APPENDIX D

Devil's Lake, North Dakota

Final
Integrated Planning Report
and
Environmental Impact Statement

PLAN FORMULATION

General Information

DEVILS LAKE, NORTH DAKOTA

INTEGRATED PLANNING REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

APPENDIX D – PLAN FORMULATION

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APPENDIX D
FORMULATION

Step One – Initial Screening of 300 cfs Outlet Plans

General

The purpose of this first step of the screening process is to summarize previous evaluation and present conclusions regarding alternatives for an outlet for Devils Lake. For this screening process, nine basic alternatives have been selected as potential outlets from previous outlet studies, as shown on the location map (Figure D-1). All of the proposed outlets discharge water from Devils Lake into the Sheyenne River. The selected alternatives were considered to have the greatest potential for being effective in drawing down the lake levels, while meeting objectives for downstream channel capacities, water quality criteria, and the ability to implement them. The proposed outlets have been developed to various extents in the past, some with extensive design performed. Although as much existing information was used as possible, some of the information presented here was developed recently for this study. The alternatives presented, grouped by location of the intake in Devils Lake, are as follows:

- West Bay
  - Twin Lakes -Pump
  - West Bay (Peterson Coulee) - Pump
  - West Bay (Peterson Coulee) – Gravity
- Pelican Lake
  - Peterson Coulee – Pump
- East Devils Lake
  - Gravity to Tolna Coulee
  - Pump to Tolna Coulee
  - Tunnel to Sheyenne River
  - Gravity to Stump Lake outlet
- West Stump Lake
  - Gravity to Tolna Coulee
- Water Treatment

The alternatives are described in the first part of this write-up. They are discussed and selections are made for carrying forward to Step 2 of the screening process.

Previous Studies

Over the past ten years, the Corps of Engineers has performed numerous studies on Devil Lake and many different outlet schemes have been considered in these studies. Information used for determining alternatives came primarily from five reports. The reports used are the “Devils Lake, North Dakota, Contingency Plan, 12 August 1996”, the “Devils Lake, North Dakota, Emergency Outlet Plan, 12 August 1996”, the “Devils

Lake Emergency Outlet, Independent Assessment, Phase I, October 30, 1997", a memorandum for record dated 14 April 1999 with the subject "Devils Lake Emergency Outlet, Alternative Cost Comparisons", and "Devils Lake Basin, North Dakota, Integrated Draft Feasibility Report and Environmental Impact Statement, April 1988".

Outlet Assumptions

There are various configurations that can be used for each alternative. Pipe materials, pump types, pump station configurations, and pipes verses open channels are a few of the choices that can be made when developing an outlet along a particular alignment. For the screening process the most logical and most developed alternatives from past work will be investigated for discussion and cost estimating.

For Step 1 of the screening, to treat all outlet alternatives equally, several constraining assumptions have been made: 1) The maximum capacity of the outlet will be 300 cfs at a lake elevation of 1445 msl. 2) Flow through the outlet will be constrained by water quality and quantity of the Sheyenne River. 3) Flow through the outlet will be controllable to increments of 10 cfs. 4) Screens will prevent fish passage through the outlet. 5) Operation of the outlet is to be limited to seven months of the year. Consideration was also given to effects of the outlet on

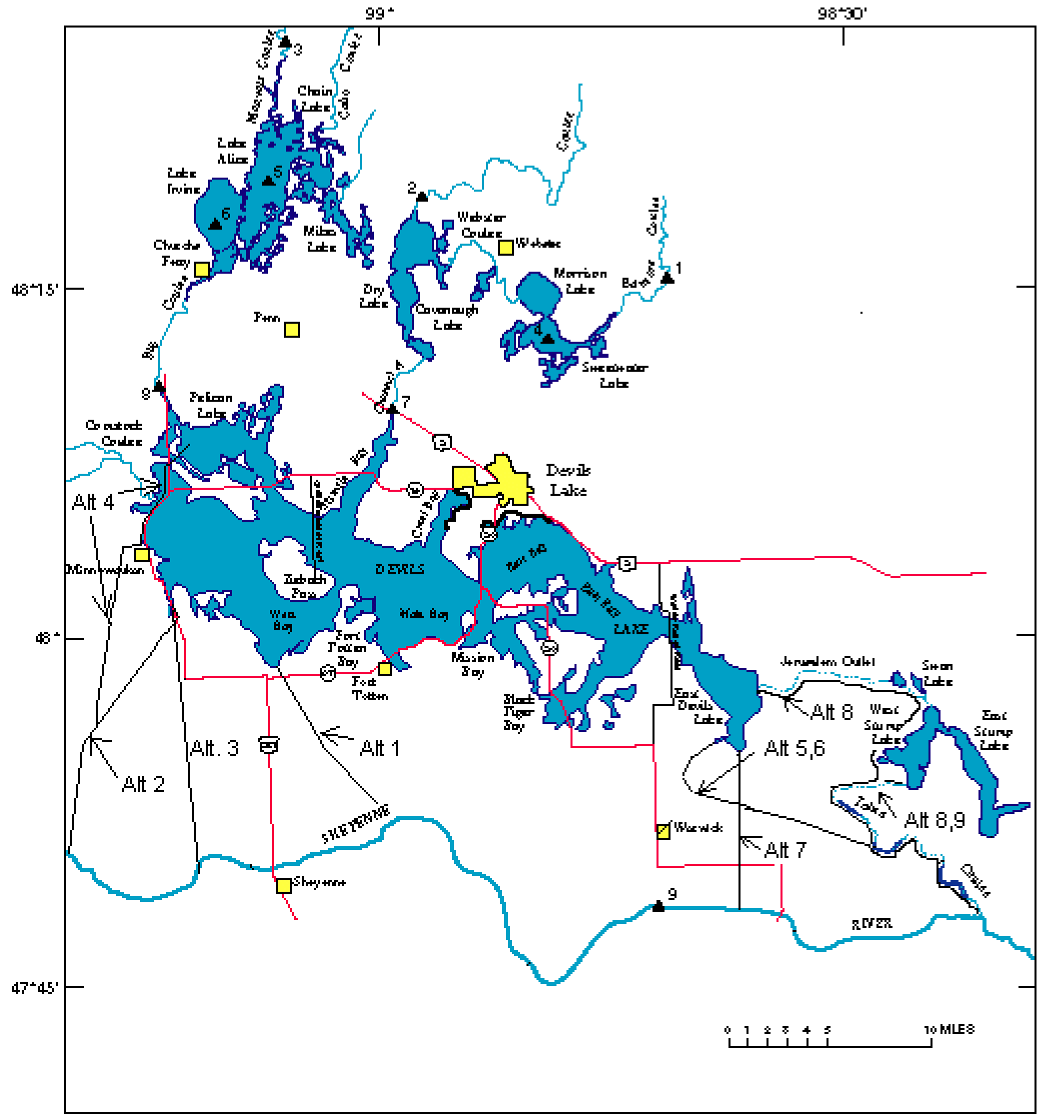


Figure D-1a

the Sheyenne and Red Rivers if it was operated with flows unconstrained by water quality because of lake level rises that threatened a natural overflow from Stump Lake.

Outlet Descriptions

West Bay Alternatives

Most outlet alternatives that have been seriously developed in the past have started in the West Bay of Devils Lake. This area has the best water quality in the lake that is located relatively near the Sheyenne River. However, even an outlet with flows constrained by sulfate concentration on the Sheyenne River will have water quality impacts on the

Sheyenne and Red Rivers. Three different basic outlets could be feasible to draw water from the West Bay.

<u>Alternative 1. Pump Along Twin Lakes Route from West Bay</u> This alternative has been investigated extensively in the past because it is the shortest and lowest route for pumping water from the West Bay of Devils Lake to the Sheyenne River. A design is summarized in the 12 August, 1996 report titled "Emergency Outlet Plan, Devils Lake, North Dakota". This outlet brings water approximately 13 miles from Devils Lake to the Sheyenne River. It uses a series of three pump stations and impoundments to bring water in steps to the top of the divide between Devils Lake and the Sheyenne River. The top of the divide is at approximately elevation 1495 feet msl. Existing natural lakes would be taken advantage of to form the impoundments. From the top of the divide to the Sheyenne River water would flow in an open channel along an existing coulee. See Table 1 for estimated costs for this alternative.

<u>Alternative 2. Pump Along Peterson Coulee Route from West Bay</u> Because of opposition from the Spirit Lake Nation over the Twin Lakes Route, an outlet from West Bay that incorporates the Peterson Coulee was substantially developed and designed in 1998. With a total length of about 14 miles and a divide elevation of 1570 feet msl, this route is slightly longer and much higher than the Twin Lakes Route. However, only the northernmost 1½ to 2 miles of this route lie within the Spirit Lake Reservation and no Tribal trust lands are impacted because affected reservation lands are all in private ownership.

The Twin Lakes outlet design developed in 1996 proposed to convert several natural lakes and wetlands, as well as an existing coulee, into storage basins and channels for the outlet. The effort for the Emergency Outlet Plan emphasized low construction cost. Environmental and social impacts were not fully considered. The opposition that outlet plans were receiving from the Spirit Lake Nation and other landowners led to greater emphasis on environmental and social impacts when making decisions regarding the configuration of the Peterson Coulee outlet. The Peterson Coulee route was therefore developed using a pipeline to convey water from Devils Lake to the Sheyenne River. This configuration minimizes impacts along the outlet route in exchange for moderate increases in estimated construction costs.

The Peterson Coulee alternative requires a high head pump station to convey water through the pipeline. The pump station would be constructed east of Round Lake and Highway 281 to draw water from Devils Lake and convey it under the highway and over the divide to the Sheyenne River. The underground pipeline would extend from the pump station on Devils Lake to the Sheyenne River and is approximately 70,100 feet (13.3 miles) long. The first approximately 14,000-foot long high-pressure section would be either ductile iron pipe or steel pipe and the remainder would be reinforced concrete pipe. See Table 1 for costs for this alternative. The section of pipeline that runs down Peterson Coulee could be replaced by open channel flow over a series of drop structure. However, past evaluations of this feature have concluded that the pipeline is preferred over the open channel.

In order to satisfy water quality constraints on the Sheyenne River and still pump at maximum efficiency for drawing down Devils Lake, a pumping system is required that can provide highly variable quantities of flow. For the 1998 design, a pumping station was designed that combined many small (10 cfs) and medium (50 cfs) sized pumps in order to be able to provide the increment of flow desired. This is the design reflected in Table 1. It is recognized now that a much less costly pump station could be constructed using just a few large pumps, such as three-100 cfs pumps. The flow from each of these pumps can only be varied by a small percentage from its rated capacity though. Constructing a small reservoir area just before the pipeline enters Peterson Coulee could provide variable flow desired. A gate on the outlet of the reservoir would allow water to be metered into the pipeline to the Sheyenne River. The level of water in the reservoir would be maintained within a set range by cycling the pumps in the pump station off and on.

<u>Alternative 3. Gravity Flow Pipelines From West Bay</u>. For this alternative, a gravity flow tunnel would be constructed from Devils Lake to the Sheyenne River. The invert of the pipe at its inlet would be at approximately an elevation of 1415. This outlet method is attractive because the costs for operation are minimal after it is completed and impacts along the outlet route are minimized. A tunnel was sized that would run directly south from the pump station location identified for the Peterson Coulee pump outlet. The tunnel along this alignment would be about 14.2 miles long and would have an interior diameter of 11-feet. Approximately seven access shafts would be required along the length of the concrete lined tunnel for construction and future maintenance. A control structure would be needed at the mouth of the tunnel to control the quantity of flow allowed into the Sheyenne River.

This plan has never been extensively pursued in the past though because of the high cost of implementing it. Several experienced tunneling contractors were contacted to help determine costs for the tunnel during the 1999 alternative study though. See Table 1 for estimated costs for this alternative.

<u>Pelican Lake Alternatives</u>

The largest inflows into Devils Lake come from Mauvais Coulee and enter Devils Lake through Pelican Lake, which is on the north side of the West Bay. Water quality in Mauvais Coulee is similar to the Sheyenne River making Pelican Lake water much fresher than the rest of the Devils Lake, particularly after high runoff events. Therefore, an outlet that intakes water in Pelican Lake is attractive because it is the freshest water available in Devils Lake. This would allow the outlet to be more effective in drawing down the lake with flows constrained for water quality than could be expected at other outlet locations. It would also have the least impacts on the Sheyenne and Red Rivers if used in an unconstrained mode to reduce the potential for a natural overflow. This intake location was briefly considered in the 1988 feasibility study. More serious consideration and conceptual designs and for an outlet from Pelican Lake were investigated in the winter of 1999 after it was found that the effectiveness of constrained flow West Bay outlets was less than desired.

Alternative 4. Outlet from Pelican Lake Pump over Peterson Coulee. The distance between a potential inlet on Pelican Lake to the Sheyenne River is a little over 22 miles. The water must be transported south across the flat Devils Lake Basin and then up and over the divide to the Sheyenne River. Peterson Coulee lies within the direct route and would be used similarly to the West Bay outlet alternative.

Based on the 1999 conceptual studies, the first step in outletting water from Pelican Lake would be along a 6.1-mile long open channel to a pump station located on the north side of Minnewauken. The channel would run from Pelican Lake through low ground and then cross Highway 281. It then would follow Highway 281 to the north side of Minnewaukan. Portions of the channel alignment are at or below elevation 1435 feet and wide enough that excavation would not be required.

From the end of the channel on the north side of Minnewauken, water would be pumped through a pipeline about 16.1 miles long to the Sheyenne River. Initial design work indicated that about 24,000 feet of the pipeline would be ductile iron or steel pipe and remainder would be reinforced concrete. The pump station and pipeline would be similar to that required for the West Bay outlet through Peterson Coulee, but would have higher head requirements due to the longer length of the pipeline.

As an alternate configuration, the Alternative 2 outlet could be constructed and Pelican Lake water could be brought to this pump station. Initial indications from concepts studied in 1999 were that this would be far more costly and have greater impacts than the concept presented above. However, there may be advantages to a staged outlet construction and this concept should be further investigated if an outlet from Pelican Lake appears to be feasible.

More fresh water would be available from Mauvais Coulee into Pelican Lake if the historical drainage route from Dry Lake to Mauvais Coulee was restored. Drainage From Dry Lake was diverted directly to Devils Lake through Channel A in 1979. Therefore, a control structure could be built at the head of channel A and a new channel would be constructed west of Dry Lake to allow flow to reach Mauvais Coulee. This feature is included in the cost estimate for this alternative.

Embankments would be needed to keep the fresher water in Pelican Lake and the gravity channel separated from the West Bay of Devils Lake. For the most part, the existing embankments for Highways 281 and 19 would be used to do this. In response to Devils Lake rises to date, Highway 281 and County Road 19 have been raised to minimum elevations of 1451.3 and 1448.8, respectively. Culverts under Highway 281 and County Road 19 would be plugged so that the road embankments would separate the freshwater channel from the higher salinity water in the West Bay. A tieback dike would be needed along the section road on the north side of Minnewaukan from Highway 281 to high ground.

A control structure would be needed where County Road 19 crosses the Big Coulee below Pelican Lake to control flow between the area north of County Road 19 and the West Bay. As presently conceived, the structure would be on the East Side of the existing bridge crossing on the centerline of the existing highway. The structure would consist of an earth embankment to block the coulee, and used gated, concrete pipes to control flow through the structure.
In addition to the control structure on Highway 19, a control structure comprising a gatewell and pipes would probably be constructed in the vicinity of the pump station. This structure would be somewhat similar to the Highway 19 control structure. This structure could have two purposes. One would be to allow West Bay water into the pump station when there is insufficient inflow from Big Coulee (in lieu of West Bay backflow to the intake at Pelican Lake). The other purpose would be to allow runoff from the west side of Highway 281 to flow into Devils Lake in case of major local precipitation or snowmelt runoff events (in lieu of backflow up the freshwater channel to Pelican Lake).

See Table 1 for estimated costs for this alternative.

<u>East Devils Lake Alternatives</u>

East Devils Lake is the closest point of Devils Lake to the Sheyenne River and also has the lowest divide elevation, 1465 feet msl, between Devils Lake itself and the Sheyenne River basin. There is a naturally formed channel along the divide that undoubtedly was an outlet from the lake during high water level periods in the distant past. The path over the divide flows naturally down a circuitous route along Tolna Coulee to the Sheyenne River. The total distance along this route is approximately 22 miles. The closest straight-line distance from East Devils Lake to the Sheyenne River is approximately 8.6 miles.

Water quality is much worse in East Devils Lake than in the western part of the lake where most runoff enters though. For this reason, outlet alternatives from this end of the lake have not been developed beyond conceptual levels in the past. Outlet alternatives from this end of the lake are considered here though because if operated in an unconstrained manner, they: 1) are low cost outlets; 2) are as effective as other alternatives in controlling further rises in lake levels; 3) avoid impacts to the U.S. Fish and Wildlife Refuge in Stump Lake; 4) significantly enhance the water quality in the entire Devils Lake, thereby creating a recreational resource for the region; and 5) provide and economic basis for quantifying the additional cost for releasing better water quality by selecting alternatives from western locations. Relatively more alternatives are presented here than for other locations on the lake because outlets from the east end of the lake have not been examined extensively enough in the past to be able to predetermine the most efficient outlet configuration.

Alternative 5. Gravity Flow Along Tolna Coulee from East Devils Lake For this alternative, an approximately 14 mile long channel would be dug from East Devils Lake to a daylight point in Tolna Coulee. The existing channel would be used to minimize depths of excavation. Water would then flow down Tolna Coulee to the Sheyenne River. As currently envisioned, the new channel invert would be at approximately elevation 1439 at East Devils Lake and the channel would slope at 0.0001 on 1 until it daylighted in Tolna coulee. The average depth of the channel would be about 20 feet with maximum cuts of approximately 30 feet. It is assumed that the channel would be grass lined but that some maintenance would be required because grass would not live long below the waterline of a frequently used channel. The concept design attempted to keep velocities in the channel low enough to prevent major erosion. A gated control structure would be required at the channel inlet (lake outlet) to control the amount of flow in the channel. Several four to seven feet high drop structures will be needed where the new channel daylights into the existing Tolna coulee and at the lower part of the coulee and where it drops into the Sheyenne River below the Tolna Dam. See Table 1 for estimated costs for this alternative.

<u>Alternative 6. Pump from East Devils Lake to Tolna Coulee</u> This alternative is virtually the same as Alternative 5 in alignment and for most of the concept. The only difference is that a pump station would be used to lift Devils Lake water up to a higher channel across the divide between East Devils Lake and Tolna Coulee. Alternatives 5 and 6 were both conceptually designed and presented here because neither had been extensively developed in the past. The channel invert for this alternative would by 1455 at the pump station and be sloped at 0.0001 on 1 until it daylighted in Tolna Coulee. Compared to Alternative 5, this alternative requires far less excavation, but it does require a pump station. This pump station would be similar in sized to the East Ditch Pump Station on the Devils Lake Levee project and would require much smaller motors for the pumps than is required for the full pipeline alternatives such as Alternative 2. One disadvantage of this plan compared to Alternative 5 is that it would not provide a large channel that could be used as an emergency spillway out of Devils Lake. The outlet would be limited to the capacity of the pump station up to very high lake levels. Estimated costs are shown on Table 1.

Alternative 7. Gravity Flow Tunnel from East Devils Lake For this alternative, a gravity flow tunnel would be constructed from Devils Lake to the Sheyenne River. A tunnel was sized that would run from the southernmost point of East Devils Lake directly south to the Sheyenne River. The tunnel along this alignment would be about 8.5 miles long and would have an interior diameter of 7-feet. Four or five access shafts would be required along the length of the concrete lined tunnel for construction and for future maintenance. A control structure would be needed at the mouth of the tunnel to control flow into the Sheyenne River.

Costs developed for the tunnel from the West Bay of Devils Lake were used to estimate costs for this alternative. See Table 1 for estimated costs for this alternative.

<u>Alternative 8. Gravity Flow Channel from East Devils Lake to Stump Lake Outlet</u>. For this alternative, the outlet from the east end of Devils Lake would be a grass lined gravity flow channel that initially would follow the natural overflow channel between Devils Lake and Stump Lake. At Stump Lake, the channel would follow the west side of the lake

until it reached the natural outlet from Stump Lake. From there it would continue along the natural Stump Lake outlet route until the channel invert intersected natural ground in Tolna Coulee. From there, Devils Lake water would flow down Tolna Coulee into the Sheyenne River. The initial, excavated, portion of the channel is about 16 miles long. The total length of the outlet from Devils Lake to the Sheyenne River is about 28 miles long.

A channel was designed that could allow 300 cfs to flow out of Devils Lake when the Lake elevation is 1446 or more. The channel as currently designed has a bottom width of 24 feet, side slopes of 4 on 1, and a bottom slope of 0.00005. The invert at the beginning of the channel would be about 1439 and daylights in Tolna Coulee at about elevation 1434. Most of the channel excavation is 5 to 12 feet deep, but through the Stump Lake outlet the required excavation depths exceed thirty feet. Below Tolna Dam, drop structures would be required to control erosion. A drop structure might also be required where the channel daylights into Tolna Coulee because the natural channel is rather steep there.

A gate structure would be needed at a road crossing on the divide between Devils Lake and Stump Lake in order to control outflows within the operational constraints of the project. However, very large inflows into Devils Lake may exceed the operationally constrained outflow limitations. This would require that excess water be passed into Stump Lake to prevent project created damages around Devils Lake. The gate structure therefore would need to be designed to pass excess flows into Stump Lake as well as control flows into the channel.

The current design incorporates features to prevent Stump Lake from inundating the channel even if Stump Lake fills to an elevation of 1459. The channel around Stump Lake follows approximately the 1448 contour and excavation from the channel would be used to construct an embankment on the Stump Lake side of the channel that would keep channel water separate from Stump Lake water. Riprap has been included in the design and cost estimate to prevent erosion of the embankment under high lake levels. If this plan was implemented, installation of the riprap could be delayed until Stump Lake actually filled.

West Stump Lake Alternatives

An outlet from West Stump Lake into Tolna coulee requires the least amount of construction of any outlet plan. The divide elevation between West Stump Lake and Tolna Coulee is just 1459.0. As with East Devils Lake, the low point is in an existing channel that obviously formed an outlet for the Devils Lake basin in some historical period. A complete hydraulic design for a West Stump Lake outlet has not been completed at this time, although a channel for the outlet has been conceptually sized. An outlet from West Stump Lake would require that Devils Lake water flow several miles over the divide between Devils Lake and Stump Lake and fill Stump Lake before it could operate. Stump Lake is currently about 35 feet lower than Devils Lake. The divide between Stump Lake and Devils Lake is approximately at elevation 1446.5 feet msl. The need to get water over the divide between the two lakes before the Stump Lake outlet would become effective may require that a higher level would need to be produced in Devils Lake compared with other plans.

After Stump Lake is filled from Devils Lake, the water in Stump Lake will still contain approximately twice the dissolved solids as in East Devils Lake. It would therefore be even less effective than East Devils Lake in lowering the lake level with a constrained flow plan. In addition, this plan would be ineffective in averting some of the great impacts on the Sheyenne and Red Rivers due to poor water quality from a natural spill. The outlet could be used as a control structure to control outflows from the lake under a natural spill condition though.

Alternative 9. Gravity Flow Along Tolna Coulee from West Stump Lake For this alternative, an approximately 5.6 mile long channel would be dug from West Stump Lake to a daylight point in Tolna Coulee. The new channel would be similar in design to the channel conceived for East Devils Lake and would follow the existing outlet channel out of Stump Lake. The channel invert would be at approximately elevation 1440 at Stump Lake and the channel would slope at 0.00034 on 1 as presently conceived. The average depth of the channel would be about 10 feet with maximum cuts of approximately 20 feet. Existing wetlands, lakes, ponds, and a dam along the current channel would complicate construction. A gated control structure would be required at the channel inlet (lake outlet) to control the amount of flow in the channel. Several five to fourteen feet high drop structures will be needed where the new channel daylights into Tolna coulee and at the lower part of the Coulee and where it drops into the Sheyenne River below the Tolna dam. See Table 1 for estimated costs for this alternative.

Water Treatment

Treatment of outlet water from Devils Lake has been briefly investigated in past reports. Treating lake water to reduce the total dissolved solids would allow much more water to be added to the Sheyenne River without exceeding water quality standards. There are several technologies being used today to desalinate water, all of them are very costly. Water treatment has been considered in all studies of the lake, most recently for the 1996 Emergency Outlet Plan report. For this report, it was found that there is a reverse osmosis plant in Yuma, Arizona that would be similar in size to what would be needed at Devils Lake. This plant is the second largest desalinization plant in the world, producing an outflow equivalent to 130 cubic feet per second (cfs) of treated water. According to information in the 1996 Emergency Outlet Plan, this plant cost over $211,000,000 to build and costs about $26,000,000 per year just to operate. Updated from 1996 to 2001 costs using the factors in Table 1, today's first cost is $240,000,000. Annualized costs using the above numbers updated to 2001 for first cost plus operation costs using the factors from Table 1 are $44,000,000 per year.

Other sources list similarly high costs for desalinating water. In its web page, the USGS indicates that costs for desalinization of seawater can range from $1300-$2200 per acrefoot (total costs). Desalinating 150 cfs for seven months per year would result in an annual cost of $82,000,000-$140,000,000 using the USGS estimates. World Bank estimates for desalinated water are $1.60 to $2.70 per cubic meter. These unit costs would result in yearly cost of $124,000,000 to $210,000,000 at 150 cfs for seven months. Optimistic planners for desalinating seawater in the Middle East hope to get costs as low as $0.50 per cubic meter. If this could be achieved in Devils Lake, it would still result in an annual cost of $39,000,000. It seems likely that a very large desalination plant at Devils Lake would approach the lower end of estimated costs per volume of water treated. Energy costs would be extremely high. The absolute minimum energy required to recover 1,000 gallons of fresh water is 2.98 kwh.

There are concerns with operating a large desalinization plant besides cost. One is finding a source for the large amount of power that would be required to run the plant. Another is finding a disposal location for the large quantities of sludge and brine that would be produced by the plant

Cost Estimates

Table D-1 lists estimates for initial construction costs and average annual costs for the eight alternatives. The cost estimates for the alternatives were developed at different times and assumptions were made to develop the total and annual costs in Table D-1. It is assumed that all costs are based on 2001 prices. For the annual costs, it is assumed that the initial cost is amortized over 50 years and that the interest rate will be 6 3/8%. Annual costs were computed assuming that the outlet is operated every year for 50 years. Less operation would decrease the annual cost for the pumping alternatives, but the comparison would not likely change significantly.

Table D-1

Item Description										
	Outlet Intake Location >>	West Bay Devils Lake			Pelican Lake	East Devils Lake				W. Stump Lake
	Alignment >>	Twin Lakes	Peterson Coulee		Peterson Coulee	Tolna Coulee				Outlet Channel
	Main Feature >>	Pumped Storage	PS W/ Pipeline	Tunnel	PS W/ Pipeline	Gravity Flow	Gravity W/ PS	Tunnel	Gravity/ Stump	Gravity Flow
	Alternative No. >>	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Estimated Construction Cost		13,336,000	50,189,000	94,355,000	note 6	36,224,000	20,521,000	61,327,000	27,541,000	12,391,000
Estimated Contingencies		5,624,000	6,250,000	33,024,000	note 6	15,856,000	6,976,000	21,039,000	10,559,000	5,455,000
Contingencies Percentage		42%	12%	35%	note 6	44%	34%	34%	38%	44%
Estimated Construction + Contingencies Cost		18,960,000	56,439,000	127,379,000	101,478,000	52,080,000	27,497,000	82,366,000	38,100,000	17,846,000
Date of Estimate		July-96	Aug-98	note 4	Aug-98	note 4	note 4	note 4	note 4	note 4
CWCCIS Factor		445.58	459.40	note 4	459.40	note 4	note 4	note 4	note 4	note 4
Current CWCCIS Factor		485.19	485.19	note 4	485.19	note 4	note 4	note 4	note 4	note 4
Update Index		1.09	1.06	note 4	1.06	note 4	note 4	note 4	note 4	note 4
Updated Estimated Construction Cost W/ Contingencies		20,645,000	59,607,000	127,379,000	107,175,000	52,080,000	27,497,000	82,366,000	38,100,000	17,846,000
Engineering & Design		3,545,000	3,000,000	23,820,000	note 1	6,249,600	3,300,000	9,884,000	4,571,880	2,142,000
Supervision and Administration		1,243,000	3,758,000	8,407,000	note 1	3,385,200	1,787,000	5,354,000	2,476,435	1,160,000
Environmental Restoration/Mitigation[5]		note 1	note 3	600,000	note 1	4,000,000	4,000,000	250,000	4,943,000	3,000,000
Real Estate		293,000	218,000	218,000	note 1	1,500,000	1,500,000	250,000	1,983,000	1,100,000
Total First Costs		25,726,000	66,583,000	160,424,000	128,508,000	67,214,800	38,084,000	98,104,000	52,074,000	25,248,000
Annual Maintenance Cost Percentage			0.50%	0.17%	0.50%	0.50%	0.75%	0.35%	0.50%	0.50%
Annual Maintenance, Percentage of Estimated Construction Cost		182,000	298,000	217,000	536,000	260,000	206,000	288,000	191,000	89,000
Annual Operation Cost Percentage			1.72%	0.00%	1.20%	0.00%	2.00%	0.00%	0.00%	0.00%
Annual Operation, Percentage of Estimated Construction Cost[6]		490,000	1,025,000	0	1,286,000	0	250,000	0	0	0
Annual Monitoring Costs		700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000
Annual Downstream Water Users Cost - Municipal		3,300,000	3,300,000	3,300,000	450,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000
Annual Downstream Water Users Cost- Industrial		32,000	32,000	32,000	1,500	32,000	32,000	32,000	32,000	32,000
Annual Cost of Total First Costs	Term 50 Years Interest 6.375%	1,718,000	4,447,000	10,715,000	8,583,000	4,489,000	2,544,000	6,552,000	3,478,000	1,686,000
Total Annual Cost		6,422,000	9,802,000	14,964,000	11,556,500	9,481,000	7,732,000	11,572,000	8,401,000	6,507,000

Alternatives Description
1 Pump and Storage along Twin Lakes route from West Bay
2 Pump and Pipeline along Peterson Coulee route from West Bay
3 Gravity flow pipelines from West Bay
4 Outlet Channel from Pelican Lake, pump over Peterson Coulee
5 Gravity Open Channel along Tolna Coulee from East Devils Lake
6 Gravity Open Channel along Tolna Coulee from East Devils Lake with PS
7 Gravity flow tunnel from East Devils Lake
8 Gravity Open Channel from East Devils lake around Stump Lake to natural outlet and Tolna Coulee
9 Gravity Open Channel along Tolna Coulee from West Stump Lake

Notes
1 Included in construction cost.
2 E&D costs for alt 2 include only A/E fees for Phases 1,2, & 3.
3 Costs not determined. Assumed to be minimal
4 Not applicable due to level of detail.
5 Costs for mitigation of adverse affects downstream not included.
6 Assumes Operation for 25 of 50 years

Summary of Alternative Evaluation

Alternative 1. Pump Along Twin Lakes Route from West Bay

Estimated First Cost: $ 25.7 million
Estimated Annualized Cost: $ 6.2 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Fair, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake itself if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake.
Social/Political Considerations: This outlet would pass through Tribal Trust Lands of the Spirit Lake nation. Opposition to the plan by the Spirit Lake Nation led to its abandonment as a feasible outlet scheme in 1996. Meetings with the Tribe held in December 2000 indicated that it is still opposed to a permanent outlet constructed on Trust Lands. There would be great impacts to land used along the route from the open channels and three permanent pump stations.
Environmental Considerations: This plan would greatly impact many natural lakes and wetlands along the direct path of the outlet. Environmental considerations in the Sheyenne and Red River in this and all other alternatives are assumed to be directly linked to water quality.
Design/Construction Considerations: Rough design has been completed. North Dakota Water Commission also is working on a design for this route.
Conclusion: Drop from further study due to opposition from Tribe.

Alternative 2. Pump Along Peterson Coulee Route from West Bay

Estimated First Cost: $ 66.6 million
Estimated Annualized Cost: $ 9.3 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Fair, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake itself if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake. At high lake levels, water from this location may not seriously affect water quality standards on the Red River (?).
Social/Political Considerations: The final plan would not greatly affect land use along the route of the outlet, but a group of local landowners have organized to prevent it. There will be high costs for operating the pump station. A large power line will need to be brought into the pump station.
Environmental Considerations: There will be some impact to wetlands along the pipe route during construction. All areas affected will be restored after completion of the project so that long-term impacts would be expected to be minimal.
Design/Construction Considerations: This plan was extensively designed in 1998. Some redesign may be desired to reduce costs, but the overall scheme and alignment is set.

Conclusion: This plan will be retained for further study.

Alternative 3. Gravity Flow Pipelines From West Bay

Estimated First Cost: $ 160.4 million
Estimated Annualized Cost: $ 15.0 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Fair, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake itself if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake.
Social/Political Considerations: Because it is mostly underground, the final plan would not greatly affect land use along the route of the outlet. There would be opposition from groups sensitive to potential uses of any plan as an inlet into Devils Lake since this plan could most easily reversed. The local sponsor would be in favor the low operating costs of this proposal.
Environmental Considerations: Environmental impacts along the outlet route are expected to be very minimal.
Design/Construction Considerations: Only conceptual designs regarding sizing of the tunnel have been completed to date. No environmental or cultural studies in potential construction areas have been completed.
Conclusion: Drop from study due to very high costs and potential political opposition due to the perception that it could be used as an inlet.

Alternative 4. Outlet from Pelican Lake, Pump over Peterson Coulee

Estimated First Cost: $ 128.5 million
Estimated Annualized Cost: $ 10.5 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Good, but could not match level of inflow in the past seven years.
Water Quality Impacts: Will very minimally exceed standards on the Red River when constrained to sulfate standards on the Sheyenne River. This is the best water in Devils Lake if used in an unconstrained manner to reduce the potential for a natural overspill from Stump Lake. It is like that some West Bay water would be still need to be used under an unconstrained flow plan though since there most likely would not be enough inflow.
Social/Political Considerations: The final plan would not greatly affect land use from the pump station to the river. The present concept does require several miles of open channel north of Minnewaukan though. This plan would benefit by raising Highways 19 and 281 near Minnewaukan, which would be a benefit to Minnewaukan and areas south and west of it. Rerouting flow out of Dry Lake may cause concern with landowner between Dry Lake and Mauvais Coulee. This plan would be the most palatable to interests downstream of the insertion point because the water quality could be relatively good.
Environmental Considerations: Environmental impacts along the pipeline route are expected to be minimal after construction. Impacts to the Pelican Lake area, in areas

identified for open channels between Pelican Lake and the pump station, or affected by the rerouting of Dry Lake outflow have not been studied. Most of these areas are currently under water.
Design/Construction Considerations: Conceptual design has been performed. Some of the alignment would be the same as Alternative 2. The many features and the operation plan for holding water in Pelican Bay and moving it to a pump station will require much more extensive analysis. In addition, cultural and environmental impacts along much of the proposed route have not been studied.
Conclusion: Carry forward for further study because of high water quality and potential effectiveness for lowering the lake.

Alternative 5. Gravity Flow Along Tolna Coulee from East Devils Lake

Estimated First Cost: $ 67.2 million
Estimated Annualized Cost: $ 9.5 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. Impacts if operated under unconstrained flows to reduce the potential for a natural spill would not my much better than a natural spill from Stump Lake. A natural spill is expected to have significant water quality impacts.
Social/Political Considerations: This plan does cross some portions of the Spirit Lake Nation Reservation. There would be great impacts from the open channels on land use along the route. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location. The local sponsor would be in favor the low operating costs of this proposal.
Environmental Considerations: This plan would greatly impact many natural lakes and wetlands along the direct path of the outlet
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Alternative 6. Pump from East Devils Lake to Tolna Coulee

Estimated First Cost: $ 38.1 million
Estimated Annualized Cost: $ 7.7 million
All considerations are the same as Alternative 5 except that there would be somewhat greater operating costs in exchange for much lower first costs.
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Alternative 7. Gravity Flow Tunnel from East Devils Lake

Estimated First Cost: $ 98.1 million
Estimated Annualized Cost: $ 11.6 million

Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. Impacts if operated under unconstrained flows to reduce the potential for a natural spill would not my much better than a natural spill from Stump Lake. A natural spill is expected to have significant water quality impacts.
Social/Political Considerations**:** This plan does cross some portions of the Spirit Lake Nation Reservation. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location. The local sponsor would be in favor the low operating costs of this proposal.
Environmental Considerations: This plan would be expected to have very minimal environmental impacts along the outlet route. Most of those would occur only during construction.
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Alternative 8. Gravity Flow from East Devils Lake to Stump Lake and Out Natural Outlet

Estimated First Cost: $ 52.1 million
Estimated Annualized Cost: $ 8.4 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Same as Alternative 5.
Social/Political Considerations: This plan was proposed and by residents of Devils Lake and has support from the community there that thinks this would be a cheap, low operation cost alternative. There would be great impacts from the open channels on land use along the route. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location.
Environmental Considerations: This plan would greatly impact many natural lakes and wetlands in the 28-mile long direct path of the outlet
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Carry forward to Step 2 because this is the locally preferred plan. Greater analysis in Step 2 will better quantify impacts of an East End outlet. However, outlets from east end of the lake only can be effective if they are operated without constraint for water quality on the Sheyenne River.

Alternative 9. Gravity Flow Along Tolna Coulee from West Stump Lake

Estimated First Cost: $ 25.3 million
Estimated Annualized Cost: $ 6.5 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Poor.
Water Quality Impacts: Will moderately exceed the standards on the Red River when constrained to sulfate standards on the Sheyenne River. Impacts if operated under

unconstrained flows to reduce the potential for a natural spill are same as a natural spill. A natural spill is expected to have significant water quality impacts.
Social/Political Considerations: This plan does cross some portions of the Spirit Lake Nation Reservation. Interests on the Sheyenne and Red Rivers would be very opposed to water taken from this location. The requirement to fill Stump Lake before operation of this plan is also a negative factor. This plan would be the cheapest for locals to cost share with, would have low operating costs, and is similar to plans conceived by people in Devils Lake.
Environmental Considerations: This plan would greatly impact many natural lakes and wetlands along the direct path of the outlet
Design/Construction Considerations: Only very rough design has been completed for this plan. No environmental or cultural studies have been performed
Conclusion: Drop from further study due to poor effectiveness and water quality and political opposition.

Water Treatment

Estimated First Cost: $+230 million
Estimated Annualized Cost: $ +44 million
Effectiveness in Drawing Down Lake Under Constrained Flows: Good
Water Quality Impacts: Water treatment would permit good quality water to be discharged from Devils Lake to the Sheyenne River. However, handling of the brine is a major concern that would need to be addressed.
Social/Political Considerations: Water treatment would require a very large plant to be built covering many acres. A very large amount of power would be needed to run the plant. There would be a great amount of resistance to dealing with the brine and other waste products produced by the plant. Downstream interests would be very much in favor of the plant. It is possible that the plant could partially resolve Canada's concern with biota. The plant would employ many people in the Devils Lake Basin. As an understatement, the great cost of operating the plant would put a great strain on financial resources in North Dakota.
Environmental Considerations: The plant and its operations would undoubtedly have a negative affect on the area that they were constructed in.
Design/Construction Considerations: No design has been performed.
Conclusion. Because of the great cost, water treatment is not considered feasible for a Devils Lake outlet.

Alternatives Carried Forward to Step 2

It appears reasonable from a water quality perspective to only carry forward Alternatives 2 and 4 for further analysis and development in Step 2. Alternative 8 will be carried forward as the locally preferred plan so that the effects of an East Devils plan can be more formally evaluated. Alternative 8 will only be evaluated with outflows unconstrained by water quality in the Sheyenne and Red Rivers.

STEP TWO – SECONDARY SCREENING

Alternatives Being Considered

There are 3 basic alternatives being considered in this second step of the screening process, but because of the need to look at a range of operating plans (bracketed by a constrained released of 300 cfs to an unconstrained release of up to 480 cfs), the following alternatives will be included in this second step of the screening.

West Bay Outlet – 300 cfs
West Bay Outlet – 480 cfs
Pelican Lake Outlet – 300 cfs
Pelican Lake Outlet - 480 cfs
Pelican Lake Bypass (PL2)
Pelican Lake Bypass (PL3)
East Devils Lake Outlet – 480 cfs
Raise Natural Outlet
Upper Basin Storage (UBS)
Expanded Infrastructure Measures (EIM)
Combination 1 (UBS, EIM)
Combination 2 (UBS, EIM, WB300)

This section summarizes the results of the alternatives analysis. The results were evaluated under two different types of analyses:

- Stochastic Analysis – average results over all 10,000 traces
- Scenario Analysis (with initial evaluation based on a wet future and two other sensitivity evaluations based on more moderate futures): wet future results based on a trace that repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993-1999) for three cycles and then assumes climatic and hydrologic conditions similar to 1980-1999.

Probability (Stochastic) Based Approach

COST EFFECTIVENESS

Economic feasibility is one of several criteria used for screening alternatives. Planning guidance directs that, all things being equal, the plan with the greatest net benefits be selected for implementation. Other criteria, though, such as social acceptability, environmental impact, technical feasibility, and effectiveness in solving the problem may influence the plan selection process. Two measures of economic feasibility, the benefit-cost ratio and net benefits, have been calculated for each alternative and are used to screen alternatives for selection of a plan.

The results of the stochastic approach to the economic analysis are presented in Table D-2. Three general benefit categories are included in the analysis. These include (1) flood protection costs avoided around Devils Lake by delaying or reducing the flood peak, (2) reduction of residual flood damages around Devils Lake and (3) downstream benefits or costs resulting from operation of the outlet or natural overflow from Devils Lake.

Table D-2

Summary of Benefits for Stochastic Analysis

	Costs for Most Likely Action Strategy				Remaining Annual Damages					Total
	Without Project	With Project	Costs Avoided	% Costs Avoided	Without Project	With Project	Damages Reduced	% Damage Reduction	Downstream Benefits	Avg Ann Benefits
West Bay Outlet - 300 cfs	$ 10,521.4	$ 9,169.8	$ 1,351.6	12.8%	$ 1,284.5	$ 1,159.2	$ 125.3	9.8%	$ 164.0	$ 1,640.9
West Bay Outlet - 480 cfs	10,521.4	7,440.3	3,081.1	29.3%	1,284.5	953.2	331.3	25.8%	(3,295.0)	117.4
Pelican Lake Outlet - 300 cfs	10,521.4	7,982.5	2,538.9	24.1%	1,284.5	1,053.6	230.9	18.0%	134.0	2,903.8
Pelican Lake Outlet - 480 cfs	10,521.4	7,136.5	3,384.9	32.2%	1,284.5	953.4	331.1	25.8%	(2,290.0)	1,426.0
Pelican Lake Bypass - 480 cfs (PL 2)	10,521.4	8,539.3	1,982.1	18.8%	1,284.5	1,084.9	199.6	15.5%	(51.0)	2,130.7
Pelican Lake Bypass - 480 cfs (PL 3)	10,521.4	6,574.8	3,946.6	37.5%	1,284.5	740.0	544.5	42.4%	(50.0)	4,441.1
East Devils Lake Outlet - 480 cfs	10,521.4	7,440.0	3,081.4	29.3%	1,284.5	953.4	331.1	25.8%	(3,295.0)	117.5
Upper Basin Storage	10,521.4	9,824.0	697.4	6.6%	1,284.5	1,209.2	75.3	5.9%	-	772.7
Expanded Infrastructure Measures	10,521.4	8,116.9	2,404.5	22.9%	1,284.5	1,279.1	5.4	0.4%	-	2,409.9
Combination 1 (UBS, EIM)	10,521.4	7,471.3	3,050.1	29.0%	1,284.5	1,204.0	80.5	6.3%	-	3,130.6
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	10,521.4	6,503.7	4,017.7	38.2%	1,284.5	1,106.1	178.4	13.9%	166.0	4,362.1

Benefit-Cost Summary

	Avg Ann Costs	Total Benefits	BCR	Net Benefits
West Bay Outlet - 300 cfs	$ 5,847.0	$ 1,640.9	0.28	$ (4,206.1)
West Bay Outlet - 480 cfs	11,232.0	117.4	0.01	(11,114.6)
Pelican Lake Outlet - 300 cfs	7,797.0	2,903.8	0.37	(4,893.2)
Pelican Lake Outlet - 480 cfs	13,790.0	1,426.0	0.10	(12,364.0)
Pelican Lake Bypass - 480 cfs (PL 2)	15,202.0	2,131.0	0.14	(13,071.0)
Pelican Lake Bypass - 480 cfs (PL 3)	21,647.0	4,442.0	0.21	(17,205.0)
East Devils Lake Outlet - 480 cfs	7,238.0	117.5	0.02	(7,120.5)
Upper Basin Storage	2,650.0	772.7	0.29	(1,877.3)
Expanded Infrastructure Measures	1,149.0	2,409.9	2.10	1,260.9
Combination 1 (UBS, EIM)	3,717.0	3,130.6	0.84	(586.4)
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	9,446.0	4,362.1	0.46	(5,083.9)

Costs avoided benefit - The analysis assumes the most likely protection strategy will be implemented as Devils Lake rises in the future without a Corps project in place. The average annual cost for this strategy is estimated at $10,521,000. Each of the alternatives under consideration will reduce these future costs either by reducing the expected lake elevations or by providing additional protection that will eliminate the need for otherwise necessary protection measures. The plan with the most impact in reducing costs is the Combination 2 plan (38 percent cost reduction) followed by Combination 1 and the 480-cfs plans which reduced costs by 29 to32 percent. The least effective plan in reducing costs was the upper basin storage plan (7 percent cost reduction). It should be noted that, of the large number of potential combination plans, the two presented in this analysis were the only ones evaluated. Combinations that include a 480-cfs outlet would yield greater cost reduction benefits.

Flood damage reduction benefit - Under the most likely protection strategy, some damage would still occur around Devils Lake as it continues to rise. These residual damages occur to land, structures, and other features not readily amenable to protection from the rising lake. Remaining average annual damage without a Corps project in place is estimated at $1,285,000. Each of the alternatives will reduce these remaining flood damages to some degree. The magnitude of damage reduction ranges from 0.4 percent for the Expanded Infrastructure Measures (EIM) alternative to 26 percent for any of the 480-cfs outlets.

Downstream benefit - An alternative may generate downstream benefits if it reduces the potential for a natural overflow and associated water treatment costs. Or it may induce additional costs if it degrades downstream water quality, thereby inducing higher water treatment costs, and increases flood damage potential. Three of the alternatives, Upper Basin Storage (UBS), EIM, and Combination 1, have either no impact or negligible impact on downstream flows if they are implemented. Downstream benefits for these alternatives are estimated at zero. The alternatives that include a 300-cfs outlet show minor downstream benefits ranging from $134,000 to $166,000. These benefits result from the reduction in the potential for a natural overflow and its associated costs. Due to constrained operation of the 300-cfs outlet, downstream water quality and quantity impacts that may translate into higher costs are limited. The 480-cfs outlets cause induced costs, primarily for municipal water treatment, if implemented. The costs range from $2.3 million for the Pelican Lake outlet to $3.3 million for the West Bay outlet. Costs for the East Devils Lake outlet were not calculated for this analysis, but they would be at least as much as those for the West Bay outlet and likely higher due to its poorer water quality.

With all benefits and costs considered, the only alternative that appears feasible using the stochastic approach to the economic analysis is the Expanded Infrastructure Measures plan. This plan has a benefit-cost ratio of 2.1. Although this plan does reduce flood protection costs by a significant amount, 23 percent, it reduces residual flood damages around the lake by only 0.4 percent. Combination Plan 1 has what may be considered a marginal benefit-cost ratio at 0.84, with the benefits of EIM carrying the plan. However, it still has a minimal effect on reducing damages around the lake, 6.3 percent, and the upper basin storage component of the plan would have significant local opposition. None of the remaining plans approach economic feasibility as they are either ineffective in lowering lake levels significantly (300-cfs outlets) or have high construction costs and downstream water treatment costs (480-cfs outlets).

HYDROLOGIC EFFECTIVENESS

To evaluate the hydrologic effectiveness of the proposed outlet plans, three sets of statistics or appraisals were developed. The first sets are elevation-frequency relationships for with and without project conditions. Elevation-frequency conveys the probability that a specified elevation will be equaled or exceeded in any given year. It is commonly used in floodplain management to establish the 100-year floodplain. The second set of statistics conveys the frequency of traces whose maximum elevations would equal or exceed specified lake levels over their 50-year period. It is a measure of risk. It is similar to elevation-frequency mentioned before, however; probability is expressed in terms of a 50-year period rather than in any given year. These two sets are presented with respect to the stochastic analysis.

The third set describes the reduction in peak and long-term lake levels. They indicate how well the outlet plans performed by drawing the lake down. This analysis is probably of most direct interest because it defines the maximum extent of flooding with and without the outlet. This set is addressed with respect to the scenarios.

Elevation Frequency

To evaluate the hydrologic effectiveness of proposed Devils Lake management measures, comparison with the existing, without project condition is necessary. A variety of analyses can be done, but the most pertinent and most applicable characterization for a terminal lake is the lake's elevation-frequency. By comparing this relationship for with and without project, a quantitative measure of the outlet's hydrologic effectiveness can be made.

Figure D-1 shows possible future levels of Devils Lake along with the probability of exceeding those levels, given initial conditions existing in October 2000. Probabilities are computed based on 10,000 traces from a statistical water mass-balance model. This is for the without-project condition. The model simulations began 01 Oct 2000 with an initial lake level of 1446.5 feet above sea level. The lake-level that is exceeded with a given probability may change depending on antecedent precipitation, lake levels, and inflows at the beginning of the simulation period. The magnitude of the change is greater during periods of extreme wet or dry conditions. Information in this figure should not be used to forecast future lake behavior, because the limited temporal resolution of the model is not sufficient for short-term prediction. It is not used to forecast actual lake levels in the near term. However, assuming stationary climatic conditions, the figure can be used by water resource managers to determine the likelihood of future lake levels.

The 1-percent exceedence frequency can be estimated for any given year in the next 50 years. As seen in **Figure D-1** it does vary from year to year but eventually reaches an equilibrium elevation value of approximately 1457**. Figures D-2 to D-7** also present the with-project elevation-frequency relationships for each alternative simulated in the stochastic analysis. The East Devils Lake 480 cfs alternative results are the same as the West Bay and Pelican Lake 480 cfs plans. These figures show reductions for each percentile. For example, the 1-percent elevation-frequency is lowered for West Bay, 480 cfs plan, by 7.5 feet.

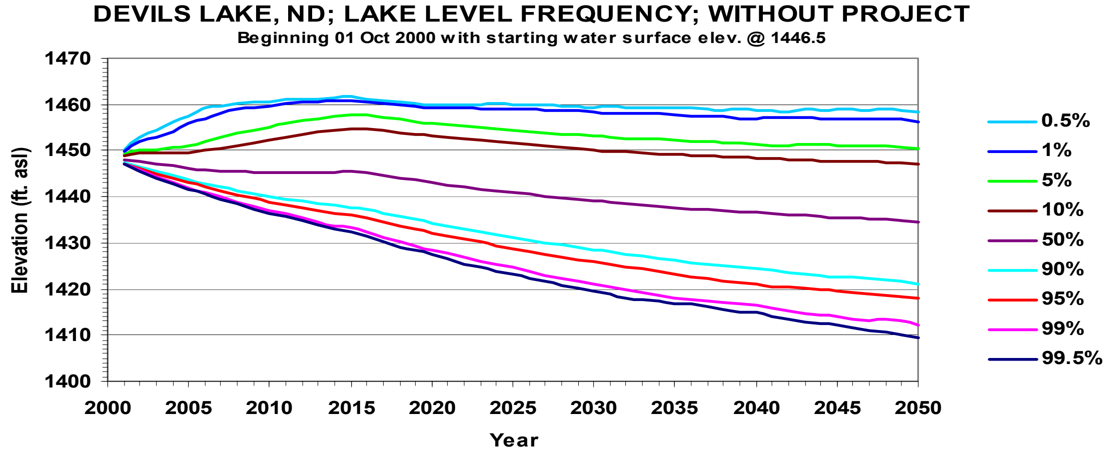


FIGURE D-1

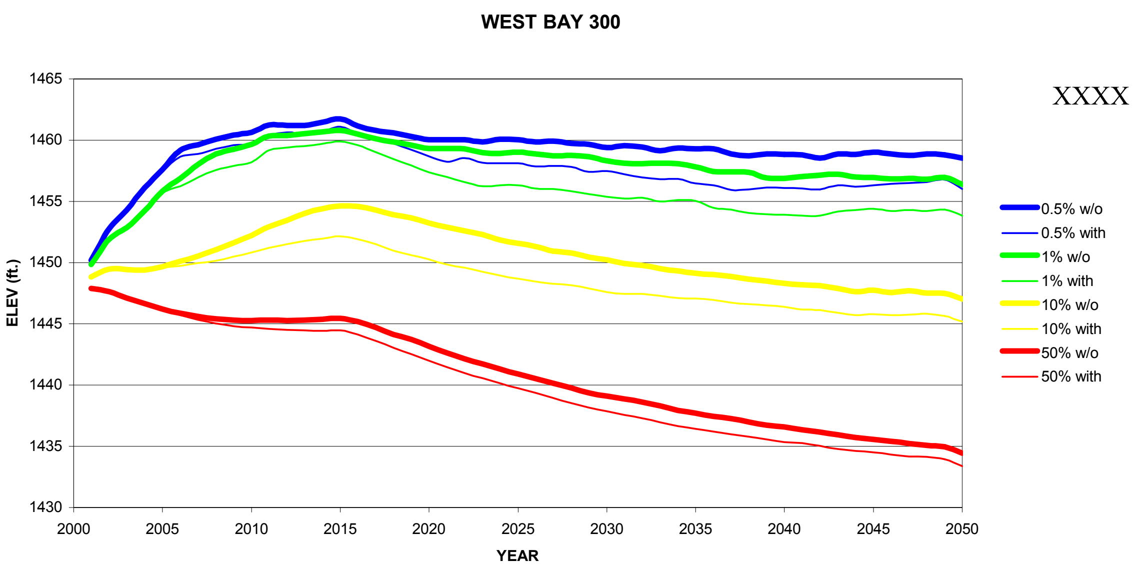


FIGURE D-2

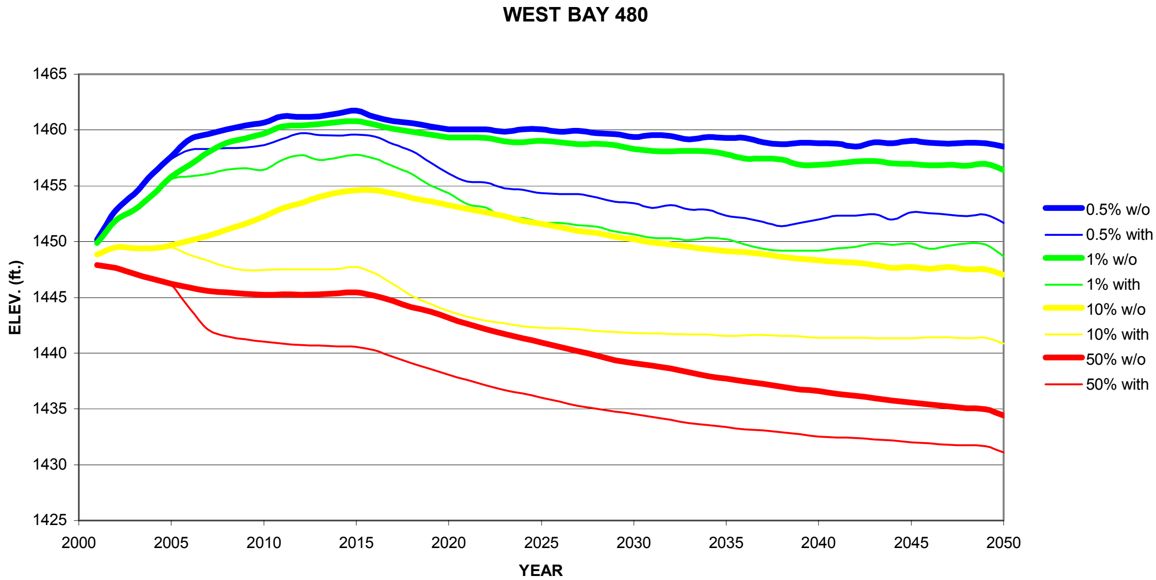


FIGURE D-3

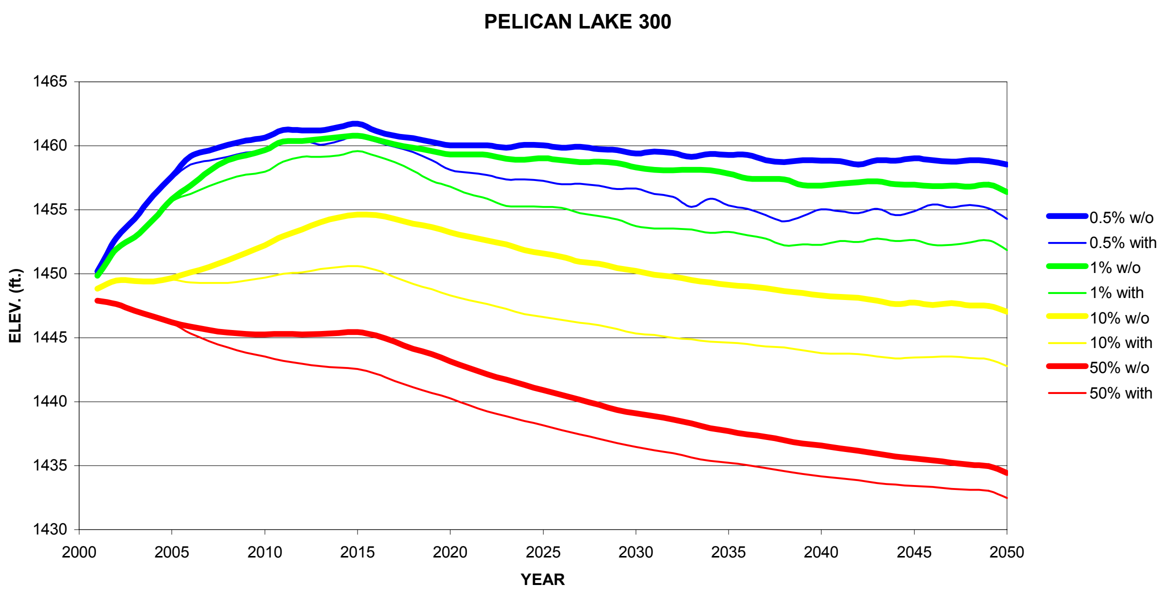


FIGURE D-4

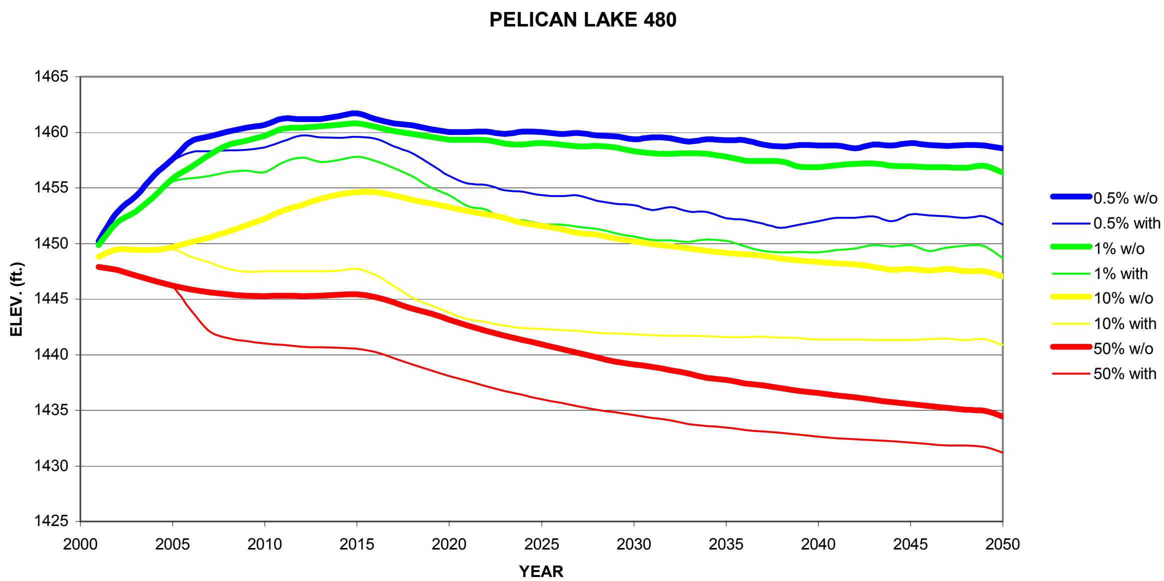


FIGURE D-5

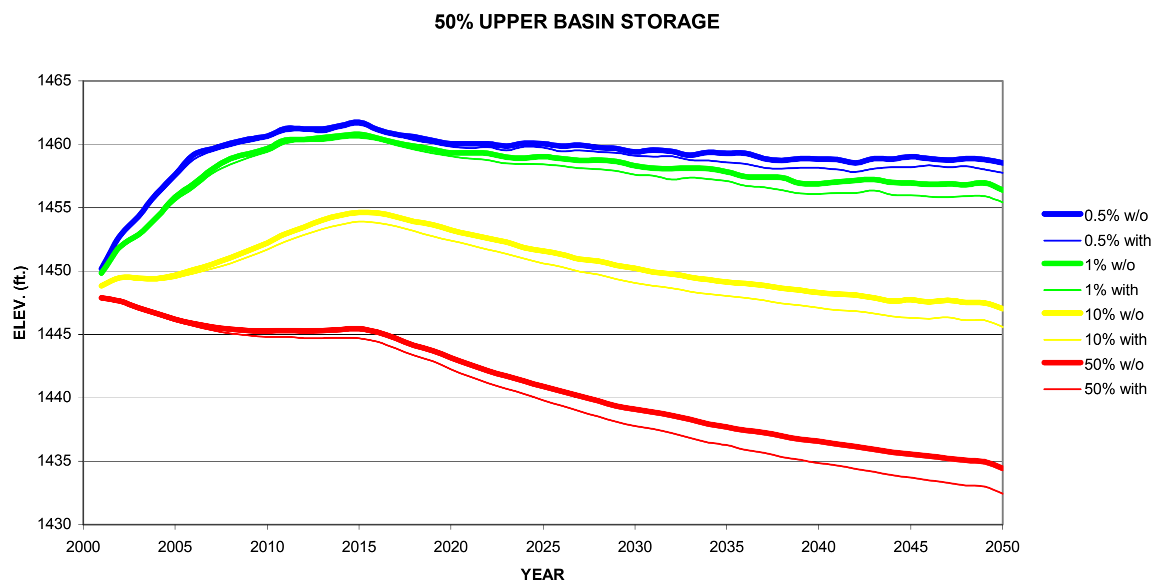


FIGURE D-6

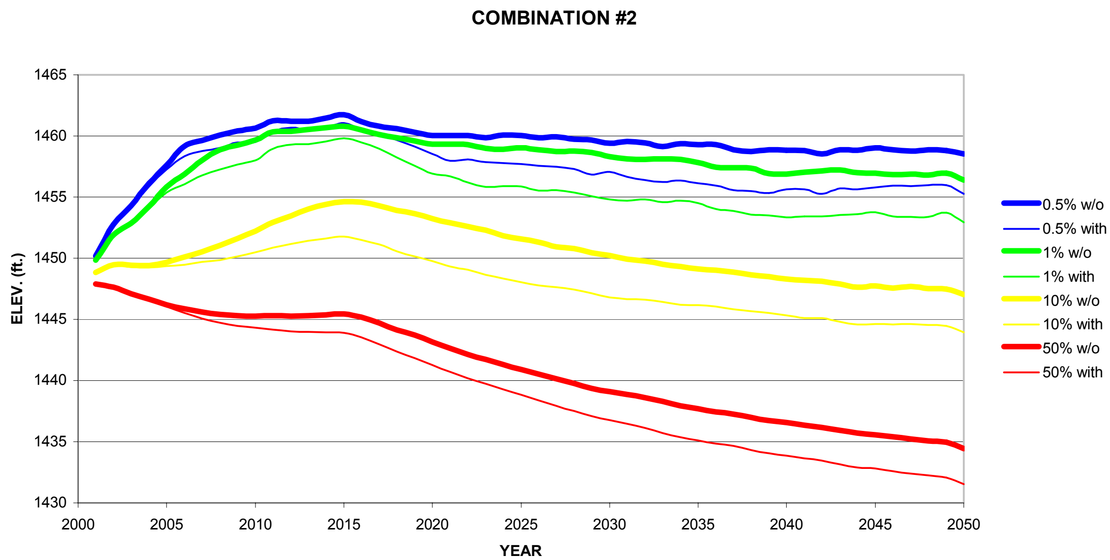


FIGURE D-7

<u>Risk of High Lake Levels</u> (stochastically based)

The other evaluation tool for plan effectiveness included the tallying of the number of traces with peak elevations that equaled or exceeded a given elevation within a specified time period. **Table 10-3** (and also shown graphically in figures D-8 and D-9) summarizes this information by listing the number of traces in percent for specified key elevations for each alternative. Examination of this table indicates, as expected, that the frequency of all lake levels is reduced for all plans.

TABLE 10-3
PERCENT OF TRACES THAT EQUAL OR EXCEED SPECIFIED ELEVATION

ELEVATION (ft. asl)	NO OUTLET	WB 300	WB 480	PL 300	PL480	EDL 480	UPPRBS[1]	COMBINATION #2[2]
1448	84.8	83.1	73.9	78.4	73.9	73.9	82.9	81.1
1450	50.6	45.2	29	36.1	29.1	29	45.6	41.3
1453	29.3	22.2	11.1	16.2	11.1	11.1	25.4	19.8
1455	20.4	14.2	6.9	10.6	6.9	6.9	17.3	12.9
1459	9.4	5.2	2.5	4.1	2.5	2.5	7.7	4.6

[1] 50% Upper Basin Storage

[2] West Bay 300cfs pump, Upper Basin Storage & Expanded Infrastructure

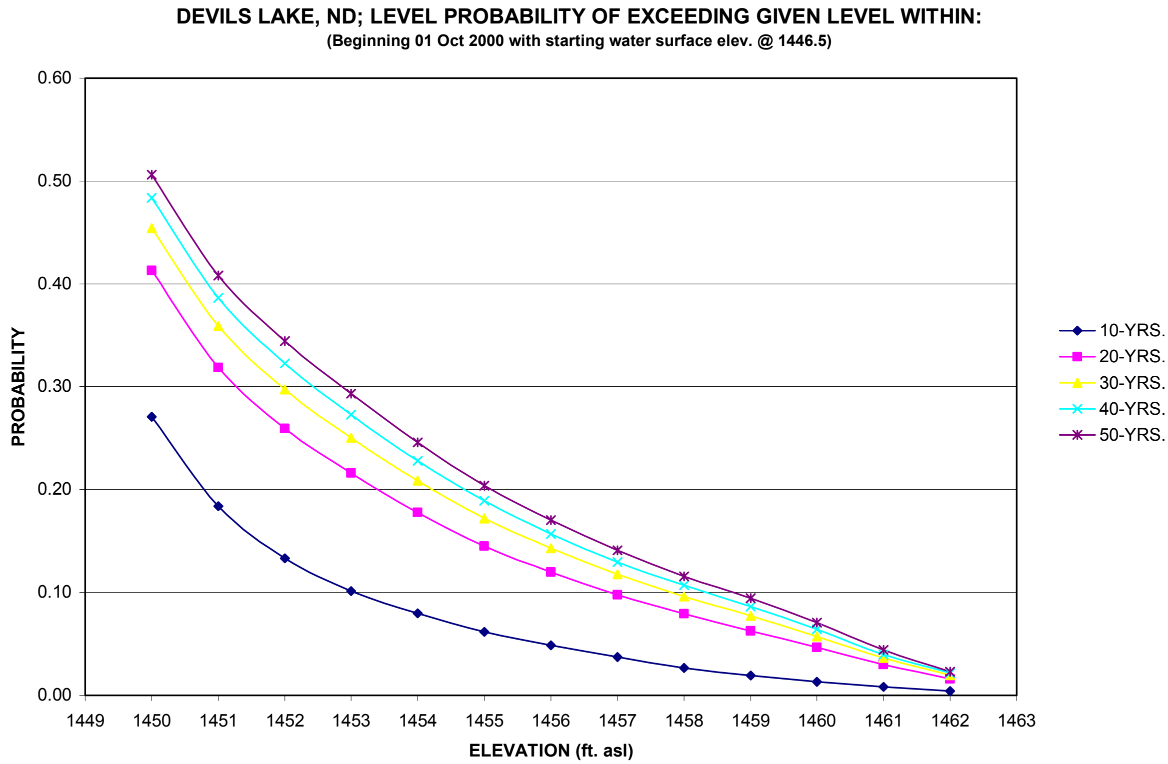


Figure D-8

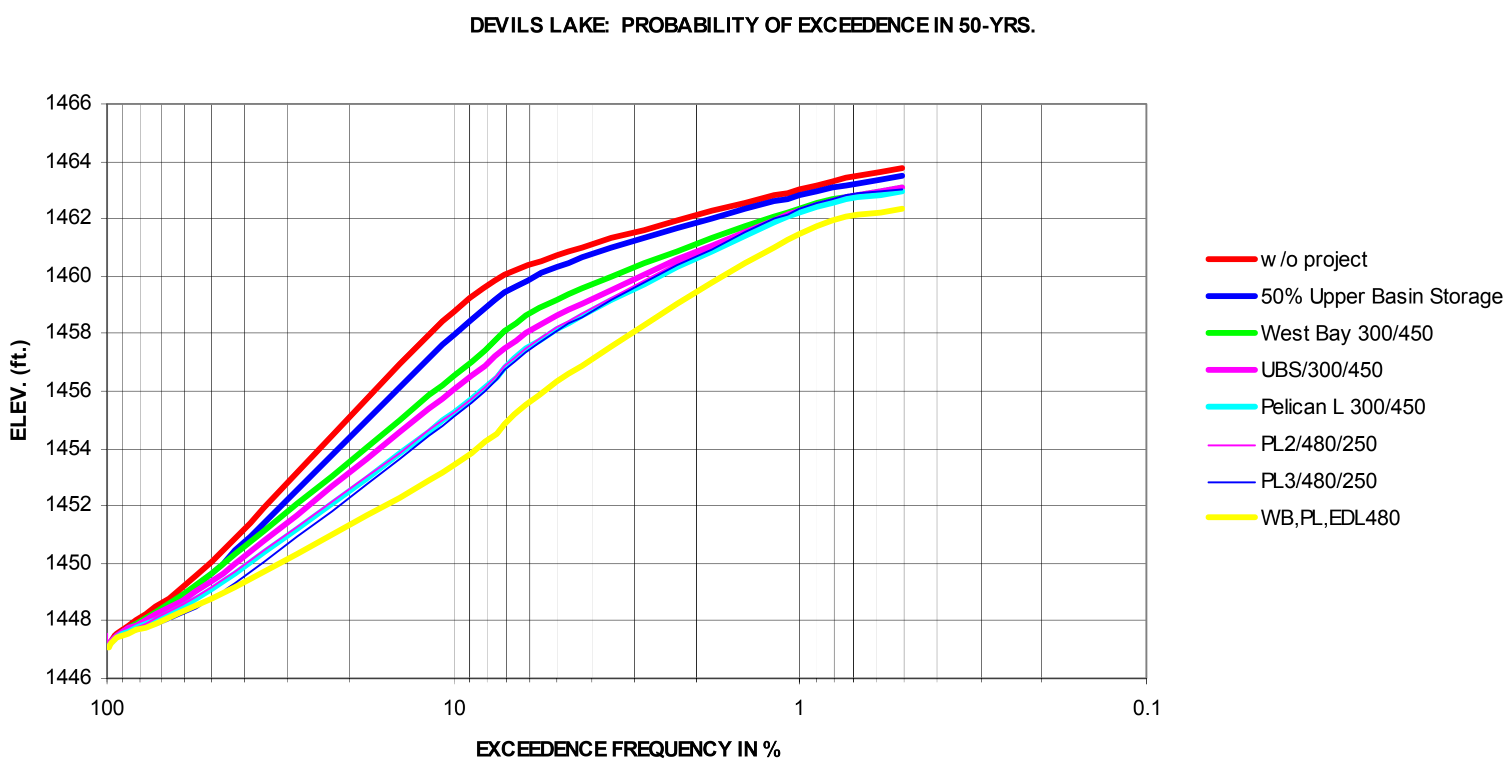


Figure D-9

ENVIRONMENTAL EFFECTS

The potential area of impact has been determined from various hydrologic, water quality, and groundwater studies associated with the construction and operation of the various alternatives. The potential impact area is based on identified changes in the flow regime, water quality, and groundwater levels.

The impact area in the upper basin is defined as the depression areas identified for restoration. The impact area around Devils Lake is separated by contour zones up to elevation 1463, which is the highest lake level attained if the lake is kept from overflowing naturally to the Sheyenne River under the wet scenario. The impact area on the Sheyenne River is defined by the flooded area outline, area of water quality and flow effects, and area of groundwater influence (1/4 mile from the river). The impact area on the Red River is defined by the area of water quality and flow effects and area of groundwater influence. Although flows and changes in stage would be less on the Red River, the area of potential groundwater influence was still assumed to be about ¼ mile.

The environmental effects of the alternatives occur in the upper basin, around Devils Lake, downstream in the Red River basin, or a combination depending on the alternative.

Outlet Alternatives

Devils Lake

Operation of an outlet would hasten successional recovery of terrestrial habitat affected by rising lake levels by lowering lake levels. To varying degrees, the outlets would reduce or enhance succession and wildlife habitat.

Likewise, to varying degrees, the outlets would have an effect on aquatic habitat through their influence on lake levels. The 300 cfs constrained outlets would have little effect on lake levels and, therefore, little effect on aquatic resources. The 480 cfs unconstrained outlets would have more effect on aquatic resources. As the lake rises, the fishery has improved through increased spawning habitat and natural reproduction. An outlet would accelerate the rate at which the lake recedes and could result in a lower lake level sooner than under natural conditions. This combined with the changes in lake water quality could result in a quicker decline of the lake fishery, than under natural conditions, as the lake recedes.

The buried pipeline would have minimal effects along the outlet route. Temporary construction impacts to wetlands and habitat would occur. There would be no long-term impacts.

Upper Basin

The outlets would have no effect on the upper basin.

Sheyenne River

Aquatic Resources

Aquatic resources would be potentially affected by changes in flow, water quality, erosion, and changes in streambank vegetation. Due to the more limited channel capacity, it is expected that effects would be most pronounced on the 110 miles of the Sheyenne River above Lake Ashtabula. Effects associated with the operation of a 300 cfs constrained outlet would be related primarily to changes in water quality. Effects associated with a 480 cfs unconstrained outlet operation plan would be related to changes in both water quality and flow.

Water quality changes for the 300 cfs constrained and 480 cfs unconstrained outlets are similar. Even under the constrained operation approach, many water quality constituents levels are increased by 2 to 3 times, to concentrations just below the established water quality standards.

The loss of habitat due to increased flows, changes in channel geometry, loss of overbank cover and sedimentation, coupled with changes in water quality and algal growth would all contribute to a substantial change in the aquatic community present in the Sheyenne River. Projected water quality changes associated with outlet operation may adversely influence fish reproduction and result in lost-year classes. The cumulative result of all these changes would be a decrease in diversity and density of aquatic species in the Sheyenne River. The threshold chloride levels for some aquatic species, such as mussels, would be approached or met with operation of an outlet, resulting in changes in species composition or diversity.

Erosion and sedimentation would increase with outlet operation. It is expected that there would be an increase in the amount of sediment deposited in the upper end of Lake Ashtabula. This combined with the increase in sulfate and TDS levels would greatly influence the aquatic resources in the lake. A decrease in species diversity and abundance in Lake Ashtabula is possible.

The operation of outlets to the Sheyenne River could have substantial erosion effects on the Sheyenne River. Studies to date have indicated that operation of an outlet could result in the loss of about 1,000 acres due to erosion and a channel migration of up to 11 feet in some reaches. Effects would be more pronounced above Baldhill Dam as the channel capacity is smaller. A more detailed erosion model that incorporates a fuller range of erosion mechanisms is being developed. The results of that model may indicate that erosion effects would be different than stated here.

In addition to the adverse impacts on habitat caused by the significant changes in stream flow proposed, the potential for physical changes in channel geometry caused by increased occurrence of bankfull or channel-forming flows is also of concern.

The changes in the aquatic community would persist for many years after outlet operation has ceased, especially on the Sheyenne River above Lake Ashtabula. The only source for recolonization in this reach of the river would be from fish populations above the insertion point of the spill as Baldhill Dam is a barrier to upstream migration of fish.

There is an increased risk of the transfer of biota or the increase in the distribution of existing organisms associated with any feature that improves the connectivity between systems that have been segregated for many centuries. The operation of the outlet would be considered such a feature. Based on available information, there do not appear to be any organisms in Devils Lake that are not already present in the Red River of the North basin. However, it cannot be said with certainty that some may not be identified or introduced in the future. In addition, the operation of an outlet or a natural overflow may improve the conditions necessary for the dispersal of organisms currently found in the Sheyenne or Red River. No mitigation feature can be said to be 100 percent effective in eliminating the risk of biota transfer. The actual effects are unknown and cannot be predicted at this time.

Terrestrial Resources

Vegetation in the riparian corridor may be affected by changes in groundwater elevation and quality, changes in frequency and duration of flooding, and induced erosion associated with increased flows. Increased flooding and erosion would be associated primarily with the operation of a 480 cfs outlet.

Based on the assumption of a ¼ mile area of influence, groundwater changes could potentially affect about 112,000 acres of riparian lands along the Sheyenne River. The table below shows that most of the land use within ¼ mile is cropland or grassland. Depending on the current groundwater elevation, there could be a change in soil moisture and vegetative characteristics. This could occur in areas where the current groundwater level is near or within 3 feet of the surface. In addition to groundwater effects, the 480 cfs outlet would result in overbank flooding. The table below also identifies the land use within the currently identified flooded area outline. Land use within the flooded area outline could be significantly affected due to increased duration of frequency of inundation.

Table D-4: Land use along the Sheyenne River

Land Use	1/4 Mile Buffer (acres)			Flooded Area (acres)		
	Above Baldhill	Below Baldhill	Total	Above Baldhill	Below Baldhill	Total
Cropland	12166	23817	35983	2014	788	2802
Woodland	7181	13125	20306	2669	2055	4724
Grassland	21141	19275	40416	3066	889	3955
Grass-Shrub	1613	2	1615	179	0	179
Wetland	5709	5669	11378	2254	1606	3860
Urban	56	2689	2745	8	427	435
TOTAL	47866	64577	112443	10190	5765	15955

Source: 30 meter Landsat Thematic Mapper 1987 through 1994
Wetland information from U.S. Fish and Wildlife Service National Wetlands Inventory (NWI)
Total wetland acreage includes 4,585 and 2,251 acres classified as river within the 1/4 mile buffer and flooded area outline, respectively

Effects on the terrestrial communities would range from losses associated with erosion to changes in vegetation composition and density as a result of saturated soil conditions from prolonged flooding and elevated groundwater levels. The degree of change that may occur due to changes in soil conditions cannot be quantified at this time. However, it is likely that a large portion of the riparian vegetation would shift from woods to a more open community type, resulting in a concurrent change in animal species composition along the river. Changes in water quality to a more saline condition could also influence the amount and type of vegetation along the river. Some of the larger overstory forest trees may survive a year or longer but with reduced vigor. Once the outlet operation is completed, recovery of these areas through succession would occur, which could take decades in some areas.

The Federally threatened western prairie fringed orchid is present in the area of the Sheyenne National Grasslands between Anselm and Kindred, North Dakota. The orchid is not found in the floodplain of the Sheyenne River, but is found in low-lying swales in upland areas more than 1 mile from the river. Therefore, it is not anticipated that the operation of an outlet would affect this species.

The States of North Dakota and Minnesota have developed lists of Natural Heritage sites that exhibit significant natural resource qualities. There are 219 Natural Heritage sites located within ¼ mile of the Sheyenne River, area of potential groundwater influence. This represents 25 percent of the Natural Heritage sites in the entire Sheyenne River basin. Within the flooded area outline along the Sheyenne River there are 24 listed Natural Heritage sites. Natural Heritage sites could be affected by changes in flow, duration, storage, and water quality.

Red River

The Red River is known for its recreational fishery, particularly for trophy catfish (MNDNR and NDG&F, no date). The MNDNR is in the process of replacing the low head dams on the river with raceways, and is trying to reestablish lake sturgeon in the river. This river also has water quality criteria within the United States (500 mg/L TDS, 250 mg/L sulfate, 100 mg/L chloride), and at the Canadian border (500 mg/L TDS, 250 mg/L sulfate, 100 mg/L chloride, 5.0 mg/L DO, 200 per 100 ml of fecal coliform) (USACE background information on water quality). Mercury accumulation is of particular concern, as methyl mercury levels in Red River fish are currently high and additional methyl mercury could be released in newly flooded areas. Background stream-bottom and fish-tissue mercury, other metals, and pesticides can be found in Brigham *et al.* (1998). Sediment transport into the Red River from the Sheyenne River with increased flows could also increase suspended sediment and sedimentation of riparian habitats (MNDNR, 1998).

Land use in the Red River basin within ¼ mile of the river is dominated by 62 percent agriculture. Woodland is second with 19 percent of the area classified as wooded. Little effect to land use is expected along the Red River. The flows are expected to have little effect on river stage and remain in the channel. Groundwater effects are anticipated to be minimal.

Operation of an outlet would result in some increases in the magnitude, frequency, and duration of elevated water quality constituents on the Red River. However, compared to the current water quality conditions in the river, these changes are not expected to be significant from an aquatic standpoint. A major effect on the fishery of the Red River is not expected.

Along the Red River there are 82 listed Natural Heritage sites within ¼ mile of the river. These sites include aquatic and terrestrial wildlife species, vegetation types, and unique communities.

Soil Salinity Effects

The outlet operation has the potential to affect soil salinity in downstream areas. There are three salinization hazards associated with a constructed outlet alternative:

(1) Induced floodplain salinization resulting from the raising of water tables of floodplain and adjacent soils in the Sheyenne Valley above a "critical depth".

(2) Additional salt loading to the floodplain could result from both overbank flooding with mixed Devils Lake/Sheyenne River water and intrusion of this water into adjacent floodplain soils as infiltrated floodwater and groundwater flow. Seepage outflow of mixed Devils Lake/Sheyenne River water could produce additional salt loading to adjacent floodplain soils during periods when the river is contained within the channel.

(3) Continued permitted use of mixed Devils Lake/Sheyenne River water to irrigate agricultural fields adjacent to the Sheyenne River and the Red River of the North.

Under the West Bay outlet alternative with an unconstrained, 480 cfs discharge rate, floodplain soils adjacent to the Sheyenne River could be frequently inundated spring through fall with more saline and more sodic water. The hydrologic conditions associated with this scenario could affect the salt status of the floodplain soils both by mobilizing existing salts stored in the soil and possibly by adding new salt.Persistent flooding would not likely occur under the Constrained Outlet Scenario being proposed. However, the combined Devils Lake/Sheyenne River discharge would likely result in altered influent/effluent relationships between the surface water in the river and adjacent groundwater systems. Under effluent (seepage) conditions associated with the constrained outlet discharge scenarios, seepage outflow from the river and the subsequent movement of this groundwater away from the channel could result in an increased salinization hazard for susceptible soils adjacent to the river.

Another salinization hazard associated with an outlet involves surface-water appropriation permittees in North Dakota and Minnesota (approximately 120, based on the North Dakota State Water Commission (NDSWC) and Minnesota Department of Natural Resources (MnDNR) permit databases) appropriating river water mixed with Devils Lake water to irrigate nearby fields. Irrigation with mixed water may be a particular concern because this water could be more saline and have a higher sodium adsorption ratio (SAR) than normal river-water.

<u>Expanded Infrastructure Measures</u>

The impacts resulting from this alternative would be similar to the proposed future without project conditions, differing only in the time at which these measures would be implemented.

Impacts to aquatic and terrestrial resources would occur due to loss of vegetation and aquatic resources from fill, excavation, removal of vegetation, increased sedimentation, relocation of structures, etc. There would be no effects in the upper basin or downstream in the Red River basin with this alternative.

If Devils Lake would continue to rise, about 155,000 additional acres would be inundated around Devils Lake and Stump Lake up to elevation 1459. Around Devils Lake, the majority of this acreage is currently cropland and fallow. Wetlands and grasslands are the next largest category of land use. Around Stump Lake, most of this area is currently grassland and wetland with cropland/fallow being the next largest category. These lands would be converted to open water wetland habitat with a corresponding change in wildlife. There are a number of Fish and Wildlife Service Wetland Easements and Waterfowl Production Areas located around the lake.

As the lake continues to rise, the Devils Lake fishery resource would probably expand up to some elevation. Natural reproduction would increase, and the density and size of the aquatic resource would probably shift to larger populations of smaller fish. As the lake continues to rise, the existing waterfowl staging area, aquatic resource, and National Wildlife Refuge at Stump Lake would be lost.

<u>Upper Basin Storage</u>

There would be no effects downstream with this alternative.

This alternative would keep some fresh water from entering Devils Lake by storing it in the upper basin. Upper basin storage would reduce the amount of fresh water entering Devils Lake. This would have a minor effect on the water quality and aquatic resources of the basin. It would result in the lake reaching higher TDS and sulfate levels sooner than compared to without storage conditions. However, due to the small amount of annual inflow reduction, ranging from 13,000 (stochastic) to 16,000 (wet scenario) acre-feet, there would be little long-term effect on water quality and the aquatic resource (based on restoration of 50 percent of the possibly drained depressions).

This alternative would store water in depressions and convert its current land use. About 75 percent of the land use in the depressions is classified as cropland or grassland. The Natural History Inventory lists 7 Natural Heritage sites located in the depression storage areas in the upper basin.

This alternative could result in a significant increase in wetland habitat, resulting in a substantial increase in waterfowl production, increased nesting/brood habitat, and migration.

This alternative would enhance storage of water in the upper basin watershed of Devils Lake, primarily by restoring wetlands that have been partially or effectively drained for agriculture. Plugging these drains has the potential to salinize additional lands by raising the water tables in areas adjacent to the storage wetlands. Areas at particular risk are existing saline wetlands or areas that are adjacent to wetlands that characteristically have a periphery of saline or saline-sodic soils (e.g. Southam, Vallers, and Hamerly soil series, Typic Endoaquolls, Typic Calciaquolls, and Aeric Calciaquolls, respectively). While some lateral movement will result in the mobilization of salts from the historic wetland edge to the new edge of the enlarged wetlands, it is believed that the majority of the secondary salinization produced by the upper basin storage alternative will result from a mobilization of salts from deep in the profile to the soil surface in areas where the water tables rise above the “critical depth”.

Not all wetlands will be similarly affected. A considerable number of seasonally ponded wetlands characterized by Tonka (Argiaquic Argialbolls) and some Parnell (Typic Argiaquolls) soils have a groundwater recharge function, and have profiles that are leached and non-saline. Soils on the periphery of these wetlands are frequently non-saline, somewhat poorly drained Aeric Calciaquolls. A lack of stored salt in these soils combined with the freshness of the runoff-component would reduce the salinity risk associated with the restoration of these wetland types. The degree of the effects on soil salinity is unknown at this time and is being studied.

Pelican Lake Outlets

Outlets from Pelican Lake would have impacts similar to those identified for the west end outlets. They would differ in some respects in water quality.

The Pelican Lake outlets would remove more fresh water from the lake, resulting in more effects to Devils Lake aquatic resources. The lake would become saltier sooner.

Downstream, the initial effects would be less because water removed would be similar to existing Sheyenne River water; only impacts resulting from increased flows would occur. Flow impacts would be similar to the West End outlets described above. In the long-term, effects to the Sheyenne River system would be similar to the other West End outlets because eventually fresh water is not available and the West Bay water, which has become saltier, because diluting fresh water has been removed, has to be taken.

East Devils Lake Outlet

An East End outlet would have similar types of effects as a West End outlet, differing primarily in the magnitude of the effects.

An outlet from East Devils Lake would result in the freshening of Devils Lake. This may or may not be desirable from a fishery standpoint because the TDS concentration is a factor in natural reproduction and reduced levels could enhance natural reproduction. The long-term effect of this could be the production of more small fish and fewer large fish.

Downstream effects would be greater than with the other outlet alternatives because poorer water is released to the Sheyenne and Red Rivers.

Scenario Based (Continued Wet Cycle) Approach

COST EFFECTIVENESS

Since the scenario based approach does not consider probabilities of future flooding events, the scenario approach to economic analysis has limited application to the alternatives screening process. However, this approach can provide information regarding the economic consequences of the wet future as defined above for the area around Devils Lake and downstream along the Sheyenne River and Red River of the North. Like the stochastic analysis, the benefit-cost ratio and net benefits have been calculated for each alternative to rank them under the wet future scenario analysis. The results of the wet future scenario approach to the economic analysis are presented in Table D-5. The same benefits that were evaluated under the stochastic approach pertain to the wet future analysis as well. With the certainty of lake level rise and eventual natural overflow intrinsic with the wet future scenario, results from this analysis are different from those of the stochastic analysis. These are briefly described below.

> *Note 1: An alternative is evaluated under the wet future scenario approach that was not evaluated under the stochastic approach, the Natural Outlet Raise plan.*
>
> *Note 2: Benefits and costs expressed on an "average annual" basis for a specific scenario assume that the scenario has a 100-percent chance of occurring. This differs from the standard definition of "average annual" which is calculated by assigning probabilities of a range of scenarios as weights in computing expected value of damages, costs, and benefits. Therefore, average annual benefits and costs in scenario context should not be considered the true expected value of benefits and costs for a project.*

Table D-6

Summary of Benefits for Wet Future Scenario

	Costs for Most Likely Action Strategy				Remaining Annual Damages					Total
	Without Project	With Project	Costs Avoided	% Costs Avoided	Without Project	With Project	Damages Reduced	% Damage Reduction	Downstream Benefits	Avg Ann Benefits
West Bay Outlet - 300 cfs	$ 39,335.0	$ 23,881.4	$ 15,453.6	39.3%	$ 4,141.4	$ 2,834.8	$ 1,306.6	31.5%	$ 2,957.0	$ 19,717.2
West Bay Outlet - 480 cfs	39,335.0	11,934.6	27,400.4	69.7%	4,141.4	1,810.4	2,331.0	56.3%	(904.0)	28,827.4
Pelican Lake Outlet - 300 cfs	39,335.0	21,815.2	17,519.8	44.5%	4,141.4	2,777.4	1,364.0	32.9%	3,028.0	21,911.8
Pelican Lake Outlet - 480 cfs	39,335.0	11,724.0	27,611.0	70.2%	4,141.4	1,810.4	2,331.0	56.3%	256.0	30,198.0
Pelican Lake Bypass - 480 cfs (PL 2)	39,335.0	19,371.5	19,963.5	50.8%	4,141.4	2,372.3	1,769.1	42.7%	569.0	22,301.6
Pelican Lake Bypass - 480 cfs (PL 3)	39,335.0	14,927.5	24,407.5	62.1%	4,141.4	1,300.1	2,841.3	68.6%	556.0	27,804.8
East Devils Lake Outlet - 480 cfs	39,335.0	11,934.6	27,400.4	69.7%	4,141.4	1,810.4	2,331.0	56.3%	(1,531.0)	28,200.4
Raise Natural Outlet	39,397.5	25,906.9	13,490.6	34.2%	3,433.3	3,066.2	367.1	10.7%	3,441.0	17,298.7
Upper Basin Storage	39,335.0	36,977.0	2,358.0	6.0%	4,141.4	3,915.1	226.3	5.5%	607.0	3,191.3
Expanded Infrastructure Measures	39,335.0	35,042.4	4,292.6	10.9%	4,141.4	4,132.9	8.5	0.2%	-	4,301.1
Combination 1 (UBS, EIM)	39,335.0	32,863.7	6,471.3	16.5%	4,141.4	3,906.8	234.6	5.7%	607.0	7,312.9
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	39,335.0	18,243.6	21,091.4	53.6%	4,141.4	2,696.3	1,445.1	34.9%	2,953.0	25,489.5

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Benefit-Cost Summary

	Avg Ann Costs	Total Benefits	BCR	Net Benefits
West Bay Outlet - 300 cfs	$ 6,376.0	$ 19,717.2	3.1	$ 13,341.2
West Bay Outlet - 480 cfs	12,188.0	28,827.4	2.37	16,639.4
Pelican Lake Outlet - 300 cfs	8,347.0	21,911.8	2.63	13,564.8
Pelican Lake Outlet - 480 cfs	14,668.0	30,198.0	2.06	15,530.0
Pelican Lake Bypass - 480 cfs (PL 2)	16,170.0	22,302.0	1.38	6,132.0
Pelican Lake Bypass - 480 cfs (PL 3)	22,753.0	27,804.0	1.22	5,051.0
East Devils Lake Outlet - 480 cfs	9,885.0	28,200.4	2.85	18,315.4
Raised Natural Outlet	20,824.0	17,298.7	0.83	(3,525.3)
Upper Basin Storage	2,650.0	3,191.3	1.20	541.3
Expanded Infrastructure Measures	4,063.0	4,301.1	1.06	238.1
Combination 1 (UBS, EIM)	6,491.0	7,312.9	1.13	821.9
Combination 2 (UBS, EIM,	11,165.0	25,489.5	2.28	14,324.5

Costs avoided benefit - The average annual cost for the most likely protection strategy assuming a wet future is estimated at $39,335,000. Except for the Natural Outlet Raise plan, which will increase costs since all features (levees, roads, etc.) would have to be constructed more than 2 feet higher than the other alternatives, all other alternatives under consideration will reduce these future costs to some degree. This is done either by reducing the expected lake elevations or by providing additional protection that will eliminate the need for otherwise necessary protection measures. The plans with the most impact in reducing costs are the 480-cfs outlets (70 percent reduction) followed by Combination 2 plan (54 percent cost reduction) and the 300-cfs plans which reduce costs by 39 to 45 percent. The least effective plan in reducing costs is the upper basin storage plan (6 percent cost reduction). It should be noted that, of the large number of potential combination plans, the two presented in this analysis were the only ones evaluated. Combinations that include a 480-cfs outlet would yield greater cost reduction benefits.

Flood damage reduction benefit - Under the most likely protection strategy, some damage would still occur around Devils Lake as it continues to rise. These residual damages occur to land, structures, and other features not readily amenable to protection from the rising lake. Remaining average annual damage without a Corps project in place under the wet future scenario is estimated at $4,141,000. The Natural Outlet Raise induces additional residual damages. Expanded Infrastructure Measures (EIM), with a damage reduction percentage of 0.2 percent, has virtually no effect on reducing residual flood damage around Devils Lake. Upper Basin Storage (UBS) and Combination 1 have a minor effect on damage reduction (5.5 and 5.7 percent, respectively). As expected, the outlet plans have the most significant impact in flood damage reduction with the 300-cfs plans reducing damages by 31 to 35 percent and the 480-cfs plans reducing damages by 56 percent.

Downstream benefit - An alternative may generate downstream benefits if it reduces the potential for a natural overflow and associated water treatment costs. On the other hand, an alternative may induce additional costs if it degrades downstream water quality, thereby inducing higher water treatment costs, and increases flood damage potential. EIM has no impact on downstream flows and thus, has no downstream benefits. The alternatives that include a 480-cfs outlet show either minor downstream benefits ($256,000 for the Pelican Lake outlet) or may actually induce costs and/or damage. This is due to high water treatment costs associated with discharges from Devils Lake. The 300-cfs outlets generate significant downstream benefits, amounting to approximately $3 million. These outlets prevent a natural overflow and the high costs and damage associated with it while at the same time causing minimal downstream impacts due to their constrained operation. The plan providing the most downstream benefits is the Natural Outlet Raise. This is by design as it is intended to prevent a natural overflow event from occurring, however, these downstream benefits are gained at the expense of the surrounding lake area by the increase in damages induced by raising the lake more than 2 feet over natural levels.

With all benefits and costs considered, every alternative appears cost effective using the wet future scenario approach to the economic analysis, except the Natural Outlet Raise alternative. While the EIM plan was the only feasible plan using the stochastic approach, it has the lowest benefit-cost ratio (1.06) and lowest value of net benefits among plans considered using the wet future scenario approach. UBS and Combination Plan 1, although cost effective under this scenario, have relatively low BCR's (1.6 and 1.13, respectively) and net benefits. The plans with the highest net benefits are the outlet plans. Of these, the 480-cfs plans have higher net benefits than their 300-cfs counterparts. Due to higher costs, though, their BCR's are somewhat lower. The plan with the greatest net benefits under the wet future scenario is the East Devils Lake 480-cfs outlet. Again, the results from this analysis of the wet future scenario are significantly different than the results from the stochastic analysis due primarily to the certainty of the lake rising to the overtopping elevation and naturally overflowing into the Sheyenne River.

HYDROLOGIC EFFECTIVENESS

<u>Reduction in Peak and Long-term Lake Levels</u>

Table 10-8 shows how each proposed alternative performed based on two measures. First is the measure of reduced peak lake level within the 50-year length of each trace. Reduction in peak level is the difference in maximum levels between the with and without outlet scenario in feet. This measurement indicates the extent that damages occur as the lake rises. Second is the measure of maximum drawdown in lake level throughout the entire 50-year length of the trace. It is the maximum difference in feet between with- and without outlet plan. **Figure D-10** shows the elevation reduction for each alternative compared with existing conditions for the WET future. **Appendix A** shows the same information for the two more moderate scenarios.

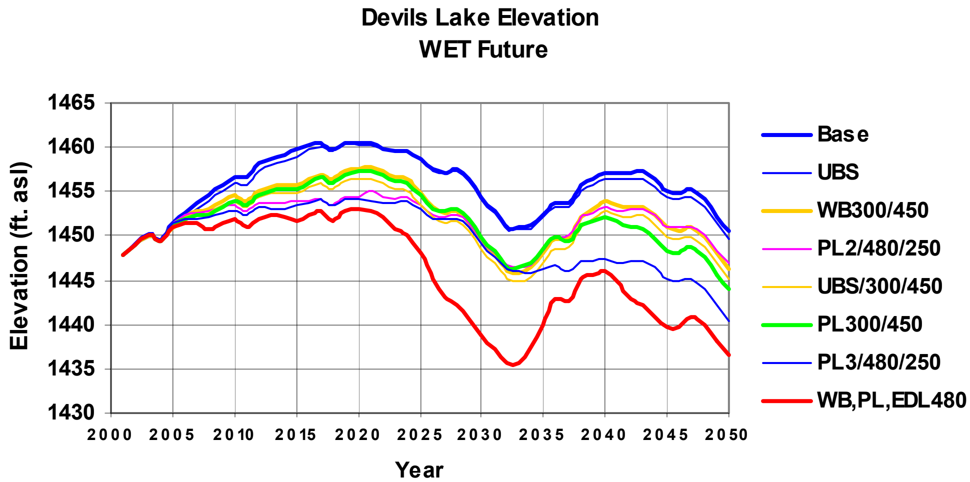


FIGURE D-10

TABLE 10-8
PEAK AND 50-YR ELEVATION REDUCTION
FOR EACH PLAN AND HYDROLOGIC SCENARIO

HYDROLOGIC FUTURE	ALTERNATIVE	PEAK ELEV. (ft.)	PEAK REDUCTION (ft.)	ELEV. AFTER 50-yrs (ft.)	REDUCTION AFTER 50-yrs (ft.)
WET	w/o project	60.59		50.59	
	WB 300	57.68	2.91	46.37	4.22
	WB 480	52.93	7.66	36.54	14.05
	PL 300	57.35	3.24	44.03	6.56
	PL480	52.94	7.65	36.62	13.97
	UPPRBS[1]	60.41	0.18	49.75	0.84
	COMBINATION[2]	56.51	4.08	45.22	5.37
	EDL 480	52.93	7.66	36.54	14.05

1 50% upper basin storage

2 Combination includes: 50% upper basin storage, West Bay 300 cfs pump, & infrastructure

WATER QUALITY CONSIDERATIONS

The State of North Dakota has classified the Sheyenne River as a class 1A stream, which establishes its designated use as suitable for aquatic life, boating and swimming, and municipal water supply use subject to treatment by softening to meet chemical drinking water requirements. The sulfate standard for class 1A streams is 450 mg/l. North Dakota has not established TDS standards for class 1 or 1A streams. North Dakota has also established an antidegradation implementation procedure in the recently revised Standards of Water Quality for the State of North Dakota, Rule 33-16-02. The antidegradation rule calls for a review process whenever a new or expanded source of pollutants would cause a significant permanent effect on the quality and beneficial uses of the affected waters. For class 1 streams, which include both the Sheyenne River and Red River of the North, a determination of "significant effect" would be if the ambient quality of any parameter were degraded by more than 15 percent, or that the available assimilative capacity were reduced by more than 15 percent, or that any pollutant load would be increased by 15 percent.

The State of Minnesota's water quality rules have established 250 mg/l sulfate and 500 mg/l TDS as standards for the Red River of the North. Other standards apply but are likely to be met whenever TDS standard is met. Minnesota also has an antidegradation policy which affords protection of designated uses based on non-numeric criteria.

The 1909 Boundary Waters Treaty identifies a set of water quality objectives, not standards, for the purpose of protecting the Red River of the North entering Canada. The numeric objectives are the same as Minnesota's numeric standards.

Water quality modeling was performed for the continued wet cycle scenario to compute the downstream routing of Devils Lake outlet water affecting water quality and flow in the Sheyenne River, the Lake Ashtabula reservoir, and the Red River of the North from the Sheyenne River confluence to the Canadian boundary at Emerson, Manitoba. The model generated daily flow and concentration data for the 50-year-long operating scenario so that the effects at any of several hundred downstream locations could be compared with the no-outlet base condition. The data was used to evaluate the impact of outlet operations with respect to regulatory compliance parameters. The data was also used to evaluate mitigation costs in the downstream water users study, potential effects on aquatic life, and potential effects on soil salinity (see other sections). In this section, discussion of downstream water quality effects focuses primarily on sulfate and total dissolved solids (TDS) because those are the parameters that are first to present regulatory challenges.

The following summary of the effects of outlet operations under the continued wet cycle describes the downstream effects in terms of the amount of time during the first ten years of operation that the sulfate or TDS standards would be exceeded. The data cited is from Tables 10-9 through 10-11. More comprehensive concentration exceedance information is presented in Appendix A, including exceedance of concentrations higher and lower than the regulatory limits. The ten-year time frame was chosen for the concentration exceedance analysis because it establishes a statistical basis for comparing the effects of all of the outlet scenarios including the moderate and dry future scenarios. The effect of the uncontrolled overflow scenario is not included in the tables because the effect of the spill does not happen in the same 10-year time frame.

300 cfs Constrained (450 mg/l sulfate and 600 cfs) – The outlet would operate mostly unconstrained by the sulfate limitation because of the abundance of relatively fresh water at the west end of the lake. There would be no exceedances of the 450 mg/l sulfate standard on the Sheyenne River but the ambient concentration would be sustained at levels above 250 mg/l for more than half of the time. With West Bay operations the TDS standard on the Red River near Halstad, MN would be exceeded 27% of the time (base condition 4%). The international objective for TDS would be exceeded 20% of the time (base condition 8%). Operations from Pelican Lake would reduce the duration of those exceedances by about one-half.

480 cfs Unconstrained – Operation from West Bay would cause exceedance of the ND sulfate standard for the Sheyenne River only 3% of the time, but the ambient concentration at Valley City would be sustained at levels above 250 mg/l for more than 70% of the time. The TDS standards at Halstad and Emerson would be exceeded 44% (4% base) and 33% (8% base) of the time, respectively. Operations from Pelican Lake would reduce the duration of those exceedances by about one-half. Operations from East Devils Lake would cause exceedances at Halstad and Emerson 59% and 48 % of the time, respectively.

Table 10-9 - Water Quality Effects
Sulfate - Percent of Time Exceeding 250 mg/l
During First 10 Years (2005 - 2014)

	Sheyenne River			Red River of the North		
Scenario	Cooperstown	**Valley City**	Kindred	Halstad	Grand Forks	Emerson
Wet Baseline	8	2	5	0	0	0
Wet 300 WB	57	55	41	0	0	0
Wet 480 WB	60	73	64	1	0	0
Wet 480 EDL	64	84	78	18	2	2

Table 10-10- - Water Quality Effects
TDS - Percent of Time Exceeding 500 mg/l
During First 10 Years (2005 - 2014)

	Sheyenne River			Red River of the North		
Scenario	Cooperstown	**Valley City**	Kindred	Halstad	Grand Forks	Emerson
Wet Baseline	82	52	73	4	0	8
Wet 300 WB	87	88	85	27	1	20
Wet 480 WB	87	90	88	44	8	33
Wet 480 EDL	88	92	91	59	29	48

Table 10-11 - Water Quality Effects Sulfate - Percent of Time Exceeding 450 mg/l During First 10 Years (2005 - 2014)						
	Sheyenne River			Red River of the North		
Scenario	Cooperstown	**Valley City**	Kindred	Halstad	Grand Forks	Emerson
Wet Baseline	0	0	0	0	0	0
Wet 300 WB	0	0	0	0	0	0
Wet 480 WB	2	3	0	0	0	0
Wet 480 EDL	51	58	34	0	0	0

Effects of Uncontrolled Overflow from Stump Lake

Figures D-11 through D-13 compare the downstream concentration effects of West Bay 300 cfs constrained and 480 cfs unconstrained outlet operations with the effects of the uncontrolled overflow condition during the first 20 years of operation. (Similar data is provided for Pelican Lake 300 cfs constrained and 480cfs unconstrained outlet operations in Figures D-14 through D-16.) For the West Bay outlets at Valley City on the Sheyenne River with outlet operations, the sulfate concentration would remain at or above 400 mg/l for much of the time during the entire 20-year period compared with the base condition where it would rarely exceed 180 mg/l. In the overflow scenario, the effects would begin to appear in the year 2014 with much higher concentration peaks and sustained higher levels. From the perspective of water users at Valley City, both scenarios would indicate the need for obtaining an alternative water supply source or extended source water treatment and acceptance of other environmental changes. An important consideration from the Sheyenne River water users perspective is that, with an outlet in place and operating, the effects of operations would be certain while the prospects for future uncontrolled spill effects would be speculative.

On the Red River near Halstad with outlet operations, the TDS concentration would remain at or above 500 mg/l (the regulatory limit) for much of the time during the entire 20-year period compared with the base condition in which the TDS standard would rarely be exceeded. In the overflow scenario, the effects would begin to appear in the year 2014 with higher concentration peaks and sustained high levels. From the perspective of people who use the Red River, and the State of Minnesota, which would have to decide to permit or not permit outlet operations, both scenarios would indicate the need for expensive alternative water supply sources or treatment technology and acceptance of other environmental changes. An important consideration from the Minnesota perspective is that, with an outlet in place and operating, the effects of operations would be certain while the prospects for future uncontrolled spill effects would be speculative.

On the Red River near Emerson, Manitoba, with outlet operations, the TDS concentration would remain at or above 500 mg/l (the Treaty objective) for more of the time during the entire 20-year period compared with the base condition in which the TDS objective would sometimes be exceeded. In the overflow scenario, the effects would begin to appear in the year 2014 with higher concentration peaks and sustained levels. From the perspective of Canadians who use the Red River, and the Province of Manitoba and the government of Canada, which would have to decide to accept or not accept outlet operations, both scenarios would result in measurable environmental changes that could be costly. An important consideration from the Canadian perspective is that, with an outlet in place and operating, the effects of operations would be certain while the prospects for future uncontrolled spill effects would be speculative.

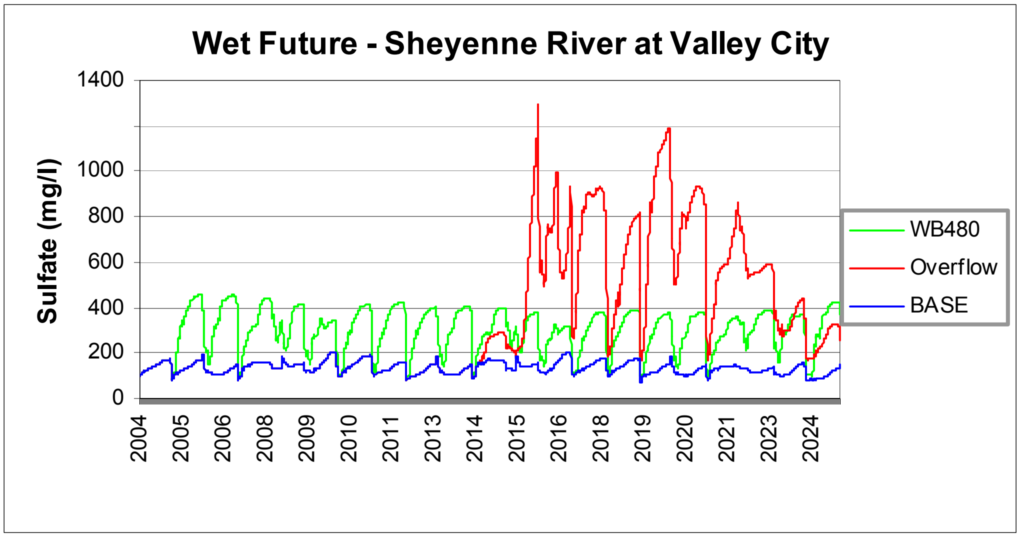


Figure D- 11

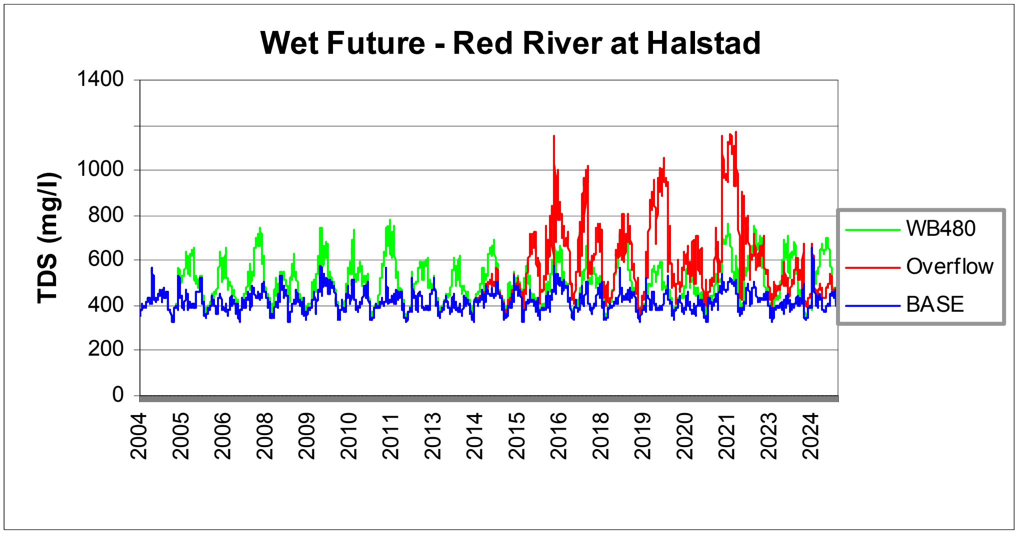


Figure D-12

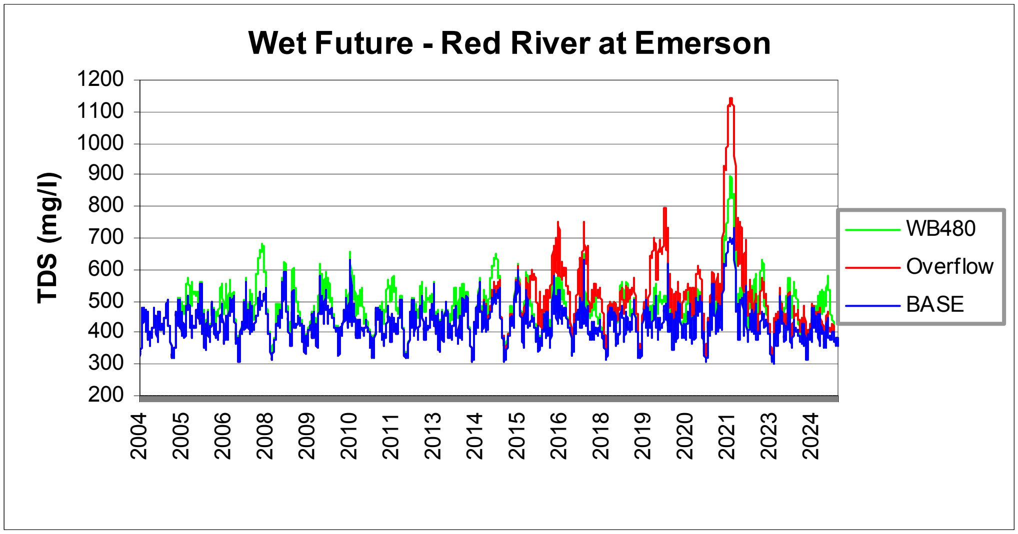


Figure D-13

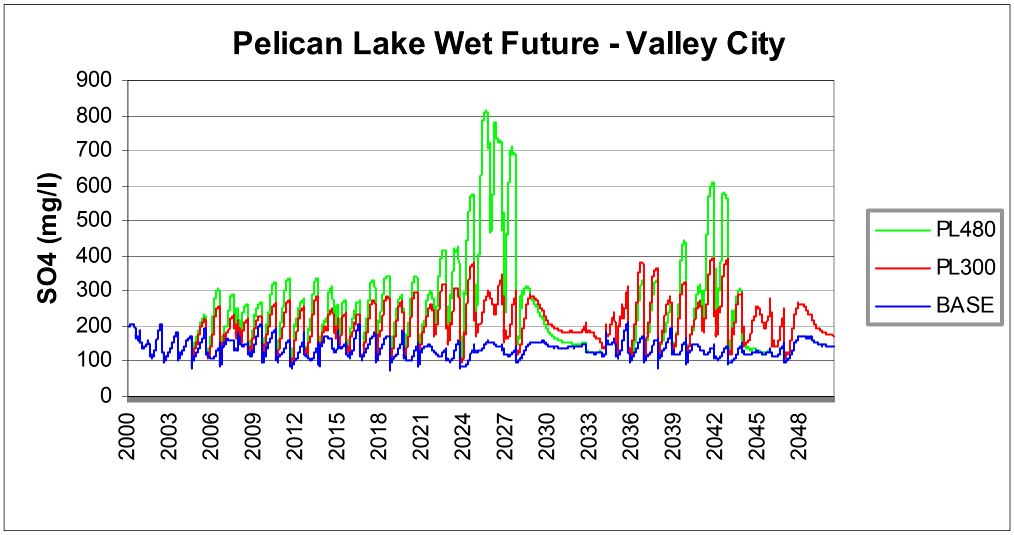


Figure D-14

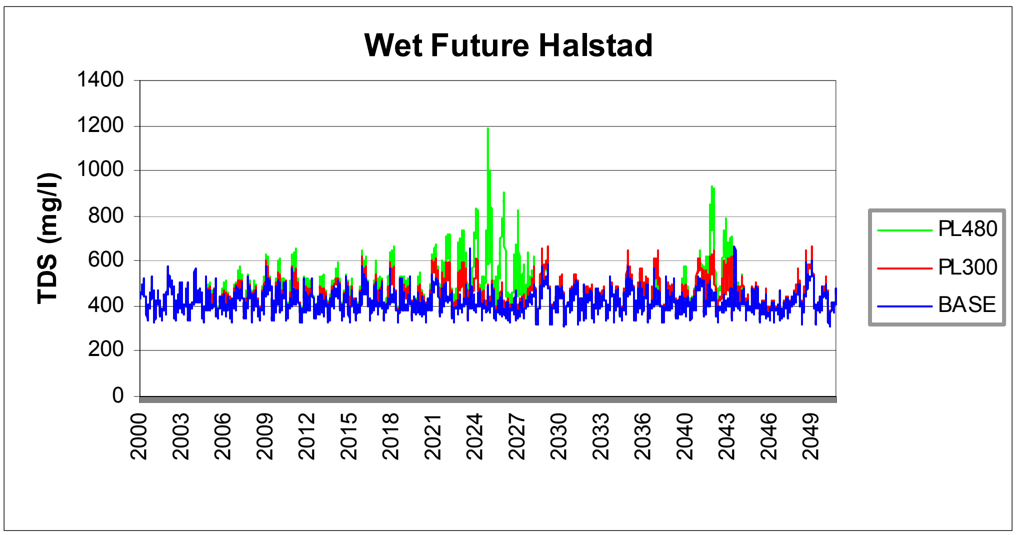


Figure D-15

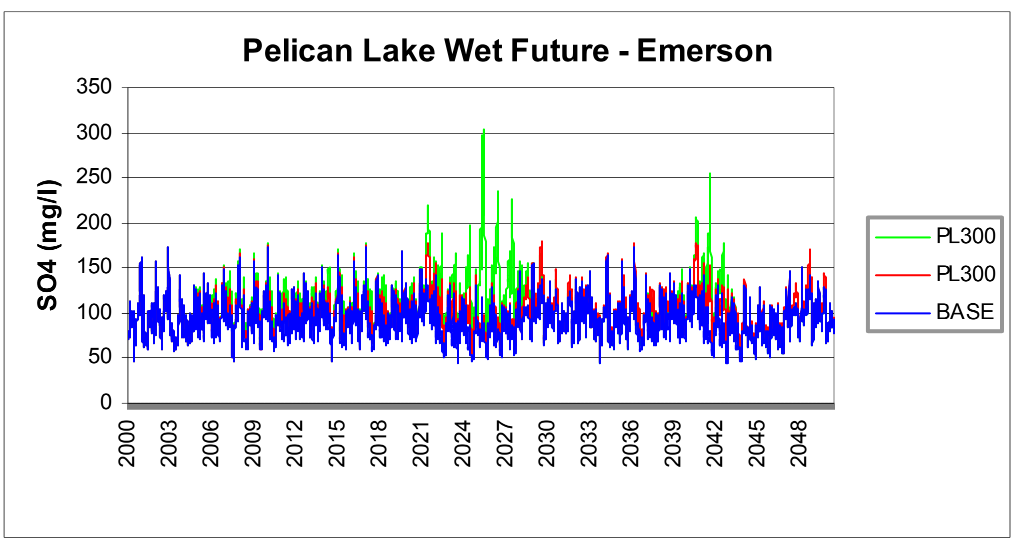


Figure D-16

OTHER ENVIRONMENTAL EFFECTS

All of the alternatives were considered under the wet future scenario also. The effects of the outlets would be similar to the stochastic analysis differing primarily in water quality and amount of flow based on the wetter future conditions. The effects based on the wet scenario are described under the stochastic analysis and in the environmental matrix presented at the beginning of the stochastic section. Two areas that are more dependent on the scenario discussion is the natural overflow event and raise the natural outlet. Those areas are discussed below.

Natural Overflow Event

A wet scenario future without involves a continuation of wet conditions resulting in increases in the level of Devils Lake to the point where the lake naturally drains through Stump Lake and the Tolna Coulee to the Sheyenne River. The scenario based future is an alternate to the stochastic (probability) based future. under the stochastic approach, the probability of a natural overflow ranges from 2 to 9.4 percent depending on the period of record used in the analysis.

A natural overflow would have similar types of effects as a constructed outlet differing primarily in the timing, magnitude, and duration of the effects.

The natural overflow event would freshen Devils Lake by removing water from the east end of the system. The effects on the aquatic resource are described in the future without project conditions. The freshened lake would result in increased natural reproduction, possibly producing more smaller fish.

The effect on terrestrial resources around the lake would be the inundation of habitat. Recovery would take a long time until the lake recedes naturally.

Downstream flow and water quality effects of a natural overflow event without erosion, would be similar to an outlet but would be more sudden. An overflow event based on the wet scenario would have a peak discharge of about 550 cfs. Other years would have an average discharge ranging from minimal to 550 cfs. By comparison, mean monthly flows on the Sheyenne River near Cooperstown range from around 11 cfs in January to a high of 549 cfs in April. Mean monthly flows near Lisbon (below Baldhill Dam) range from a low of 25 cfs in October to a high of 600 cfs in April. The maximum overflow would be similar to a 480 cfs unconstrained outlet but would be of a shorter duration, approximately 10 years. At elevation 1459, the water would be fresher but would still result in significant and long-term effects to downstream aquatic resources.

Impacts to downstream terrestrial resources and erosion would be similar to those described for the outlet alternatives.

The natural overflow has essentially the same salinity hazards of floodplain soil salinization and irrigated soil salinization as those associated with the constrained and unconstrained scenarios of the Outlet Alternatives described under the stochastic future. However, the magnitude of the associated salinization hazards is greater because of the higher levels of salinity that would be associated with Stump Lake water.

Raise Natural Outlet

Under the wet scenario, it is predicted that the lake would rise to about elevation 1463 if a dam was constructed at Tolna Coulee and the water was kept in the lake and not allowed to overflow to the Sheyenne River.

If the lake continued to rise and a dam were constructed at the natural outlet on Tolna Coulee, an additional 186,000 acres of land would be inundated up to elevation 1463. This would adversely affect land uses around the lake but would eliminate any downstream effects due to a natural overflow or erosion of the natural outlet.

Evaluation of Sensitivity Analysis Results

To better understand the sensitivity of assumptions used for future lake conditions, both with and without project, the alternatives were evaluated in comparison to other possible conditions. Variances in the assumed base conditions (future without project) that were studied under the sensitivity portion of the analysis include the following:

- No Action (including an evaluation of the cost effectiveness of incremental infrastructure protection, referred to as Maximum Infrastructure Protection)
- Moderate Future 1 (Maximum lake elevation of 1450)
- Moderate Future 2 (Maximum lake elevation of 1455)
- Erosion of the Natural Outlet

No Action

This sensitivity analysis performed a check assuming that no additional action would take place to protect infrastructure around the lake during future lake level rises. As noted in the following table, the No Action protection strategy assumption for the stochastic analysis resulted in higher net benefits for all alternatives, except Expanded Infrastructure Protection, as compared to the net benefits computed for the Most Likely protection strategy. However, under the stochastic future analysis, net benefits under the No Action protection strategy were negative for all of the alternatives, just as they were for the Most Likely protection strategy. Therefore, even this extreme case for assuming actions in the basin, which increases the benefits of an outlet, does not make outlet alternatives cost effective under the stochastic derived future.

Table D-12

Summary of Benefits for Stochastic Analysis

	Costs for No Action Strategy				Remaining Annual Damages					Total
	Without Project	With Project	Costs Avoided	% Costs Avoided	Without Project	With Project	Damages Reduced	% Damage Reduction	Downstream Benefits	Avg Ann Benefits
West Bay Outlet - 300 cfs	$ -	$ -	$ -	0.0%	$ 25,128.2	$ 22,367.8	$ 2,760.4	11.0%	$ 164.0	$ 2,924.4
West Bay Outlet - 480 cfs	-	-	-	0.0%	25,128.2	16,385.3	8,742.9	34.8%	(3,295.0)	5,447.9
Pelican Lake Outlet - 300 cfs	-	-	-	0.0%	25,128.2	19,917.5	5,210.7	20.7%	134.0	5,344.7
Pelican Lake Outlet - 480 cfs	-	-	-	0.0%	25,128.2	16,392.3	8,735.9	34.8%	(2,290.0)	6,445.9
Pelican Lake Bypass - 480 cfs (PL 2)	-	-	-	0.0%	25,128.2	21,346.2	3,782.0	15.1%	(51.0)	3,731.0
Pelican Lake Bypass - 480 cfs (PL 3)	-	-	-	0.0%	25,128.2	16,948.4	8,179.8	32.6%	(50.0)	8,129.8
East Devils Lake Outlet - 480 cfs	-	-	-	0.0%	25,128.2	16,385.3	8,742.9	34.8%	(3,295.0)	5,447.9
Upper Basin Storage	-	-	-	0.0%	25,128.2	23,570.5	1,557.7	6.2%	-	1,557.7
Expanded Infrastructure Measures	-	-	-	0.0%	25,128.2	24,812.9	315.3	1.3%	-	315.3
Combination 1 (UBS, EIM)	-	-	-	0.0%	25,128.2	23,258.1	1,870.1	7.4%	-	1,870.1
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	-	-	-	0.0%	25,128.2	20,993.8	4,134.4	16.5%	166.0	4,300.4

Benefit-Cost Summary

	Avg Ann Costs	Total Benefits	BCR	Net Benefits
West Bay Outlet - 300 cfs	$ 5,847.0	$ 2,924.4	0.50	$ (2,922.6)
West Bay Outlet - 480 cfs	11,232.0	$ 5,447.9	0.49	(5,784.1)
Pelican Lake Outlet - 300 cfs	7,797.0	$ 5,344.7	0.69	(2,452.3)
Pelican Lake Outlet - 480 cfs	13,790.0	$ 6,445.9	0.47	(7,344.1)
Pelican Lake Bypass - 480 cfs (PL 2)	15,202.0	$ 3,731.0	0.25	(11,471.0)
Pelican Lake Bypass - 480 cfs (PL 3)	21,647.0	$ 8,129.8	0.38	(13,517.2)
East Devils Lake Outlet - 480 cfs	7,238.0	$ 5,447.9	0.75	(1,790.1)
Upper Basin Storage	2,650.0	1,557.7	0.59	(1,092.3)
Expanded Infrastructure Measures	1,149.0	315.3	0.27	(833.7)
Combination 1 (UBS, EIM)	3,717.0	1,870.1	0.50	(1,846.9)
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	9,446.0	4,300.4	0.46	(5,145.6)

As noted in the following table, under the Wet Scenario, the No Action protection strategy does not make much difference in the conclusions that can be drawn about cost effectiveness. The net benefits for both 300 cfs constrained flow outlet alternatives actually decrease slightly under the No Action protection strategy versus the Most Likely protection strategy.

As shown on the Table 10-17, the Continued Infrastructure Protection, or as referred to in this appendix as "Maximum Infrastructure Protection alternative" was also compared to the no action base. This alternative represents implementation of features assumed to take place with the base condition. This showed positive net benefits for the stochastic based future and for the wet future. This shows that incremental flood protection, as has been taking place in the basin as the lake has risen in the past, is cost effective. Positive, but lesser, net benefits were also computed when Maximum Infrastructure was analyzed for the stochastic based future in combination with the Upper Basin Storage alternative and with the 300 cfs West Bay Outlet alternative. Under the Wet Future scenario, the net benefits for the combinations were greater than for Maximum Infrastructure analyzed alone. This demonstrates that when outlets and other lake reduction measures have positive net benefits when analyzed on their own, they are also cost effective when looked at relative to other flood protection measures taking place around the lake. If they do not have positive net benefits on their own, they certainly will not be cost effective compared to infrastructure protection measures.

Table 10-17

Comparison of Sensitivity Analysis Results: Maximum Infrastructure Protection Alternatives (all dollar amounts in millions)

Analysis Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Damages Prevented by Project (%)	Costs Avoided by Project (%)	Highest Lake Level[6]	Downstream Damages Avoided (%)7	Annual Project Costs[2]	First Costs[3]	BCR
Stochastic Analysis									
ST-2a	Maximum Infrastructure Protection	$14.6	95%	0%	1458	0%	$9.3	$136.7	2.57
ST-7a	Combination 1M - Upper Basin Management and Maximum Infrastructure Protection	$12.7 [4]	95%	0%	1458	NA	$11.2	$165.6	2.14 [5]
ST-8a	Combination 2 M– West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$8.2	96%	0%	1456	1%	$15.9	$221.3	1.52
Wet Future Scenario Analysis									
WF-2a	Maximum Infrastructure Protection	$34.5	95%	0%	1460	0%	$39.1	$579.5	1.88
WF-7a	Combination 1M - Upper Basin Management and Maximum Infrastructure Protection	$35.1	95%	0%	1460	4%	$39.4	$589.2	1.89
WF-8a	Combination 2M– West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$48.6	97%	0%	1456	19%	$29.4	$412.6	2.65

1 The net benefits listed include the downstream impacts, where available. Downstream impacts are not available for an alternative if the downstream costs and damages were not analyzed for the alternative. Alternatives where downstream impacts are not available are shown with a "4".

2 Annual project costs include all project costs (annualized) plus annual operation, maintenance, and monitoring costs.

3 First costs include outlet construction costs, upper basin storage implementation, natural resources mitigation, and alternative water treatment costs. The first costs include the costs for implementation of the most likely action strategies to protect features that are adjacent to Devils Lake. These costs would not necessarily be incurred at the start of the 50-year future, but would be incurred as the lake level rises.

4 Net benefits without downstream impacts considered. Actual net benefits would be expected to vary slightly from those shown.

5 Based on benefits without downstream impacts considered. Actual BCR's would be expected to vary slightly from those shown.

6 Based on the 10% probability lake level.

7 The percent of downstream damages avoided is based on the computed without-project condition damages. The assumptions for without-project conditions vary depending on the category.

Maximum Infrastructure Protection alone shows no effect on the peak lake levels. Similarly, this approach will not reduce or prevent any natural overflows from Devils Lake. Therefore, this approach has no downstream impacts. The benefits of Maximum Infrastructure Protection are the reductions in infrastructure damages, which are decreased by 95% as a result of the flood protection measures (under both the stochastic and Wet Future Scenario analyses). The annual net benefits of this approach to flood management are positive, indicating that the Maximum Infrastructure Protection measures are economically justified under both the stochastic and Wet Future Scenario analyses.

<u>Combination 1M</u>

This combination reduces the peak lake level by less than 1 foot on average. Although this will reduce the natural overflows from Devils Lake, the associated prevention of damages to downstream features was expected to be negligible under the stochastic analysis and was therefore not computed. Under the Wet Future Scenario analysis, the downstream damages are reduced by 4%. The benefits of this combination also include the annual reductions in infrastructure damages, which are decreased by 95% as a result of the flood protection measures (under both the stochastic and Wet Future Scenario analyses). The annual net benefits of this combination are positive, indicating that the combination Upper Basin Management and Maximum Infrastructure Protection alternative is economically justified under both the stochastic and Wet Future Scenario analyses. Examination of the results of the stochastic analysis shows, however, that the Maximum Infrastructure Protection alternative is better off without the addition of Upper Basin Management. The BCR for the Maximum Infrastructure Protection alternative becomes smaller when Upper Basin Management is added.

Combination 2M

This combination reduces the peak lake level about 3 feet at the 10% probability level and about 1 foot at the 50% probability level under the stochastic analysis and by 4.1 feet under the Wet Future Scenario. Benefits include the average annual reductions in infrastructure damages (at about 96% to 97%) and the reduction of downstream damages (1% under the stochastic analysis and 19% under the Wet Future Scenario analysis). The combined annual benefits of this combination are positive. Because the net benefits are positive, the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Maximum Infrastructure Protection alternative is economically justified under the stochastic analysis.

The Maximum Infrastructure Protection sensitivity analysis indicates that all of the alternatives that include Maximum Infrastructure Protection provide positive annual net benefits. When Maximum Infrastructure Protection alone is considered, the net benefits are larger than those of any other alternative. This is true both for the stochastic and the Wet Future Scenario analysis. The implementation of the Maximum Infrastructure Protection measures within the basin is therefore economically justified.

Combining Maximum Infrastructure Protection measures with other projects within the basin provides a larger net benefit under the Wet Future Scenario. This implies that the wetter the future, the more that multiple types of projects are required in the basin to relieve the flooding. There is little financial risk with the maximum infrastructure measures: the incremental protection measures are completed as required and the total project costs are spread over a several-year duration. A shortcoming of implementing the Maximum Infrastructure Protection measures alone is that the measures do nothing to relieve the prolonged flooding problems while the wet period continues. This condition can be expected to be stressful for local agencies and residents.

Although there was not a formal evaluation of a relocation alternative for the entire Devils Lake basin, the value of buildings and infrastructure around Devils Lake was estimated in 1998 to be approximately $1 billion (see reference). Relocation of most features was considered in the current economic analysis. Costs for relocation of features is dependent on the structure type and location. Relocation of isolated residential structures and outbuildings can be done for somewhat less than the value of the structure. Relocation of large buildings and city infrastructure may result in relocation costs that are somewhat more than the value of the structure. However, the costs on whole would not vary greatly from the value of the building or infrastructure. The value of the buildings and infrastructure, $1 billion, can therefore be used as an estimated cost for complete relocation cost around Devils Lake.

Ref: Technical Report "Benefits and Costs of Alternative Emergency Outlets for Devils Lake North Dakota: The North Dakota State Water Commission Temporary Emergency Outlet And The US Army Corps of Engineers Permanent Emergency Outlet." Prepared by Hazard Mitigation Economics Inc., September 27, .1999.

Moderate Future Scenarios

Cost Effectiveness

The Moderate Future scenarios must be compared to the Wet Future scenario in order to be evaluated. Net benefits for the Most Likely protection strategy for all of the alternatives evaluated for the moderate futures are negative, except for the 300 cfs constrained flow outlet from Pelican Lake in the moderate scenario with a peak lake elevation of 1455 feet msl. The West Bay 300 cfs constrained flow outlet has net benefits that are negative but approaching zero. Based on cost effectiveness, none of the alternatives can be economically justified by the analysis performed under the two moderate future scenarios.

This sensitivity analysis evaluated two scenarios that are representative of categories of moderate future lake levels (peak stages of elevation 1455 and 1450). These future lake levels alter the damages prevented and the cost savings of each alternative, and therefore affect the net benefits. In general, the wetter the future, the more damages that can be prevented and costs that can be saved by the alternatives. In futures where a natural overflow to the Sheyenne River occurs, the alternatives can be credited with additional benefits due to reductions in the downstream impacts during the wetter futures (by reducing the duration of the overflow, or by preventing it altogether). No overflow occurs during these moderate futures (without a project). Therefore, the 1455 Moderate

Future results indicate larger net benefits for the alternatives than the 1450 Moderate Future. The 1450 Moderate Future are similar to the results computed under the stochastic analysis. This is understandable, because the average and median peak lake levels are similar to the average stochastic levels.

Data in Table D-18 include the net benefits, the percent of damages prevented adjacent to the lake, the percent of costs avoided by the outlet, the peak lake level, the downstream damages avoided for each alternative, annual project costs, first costs, and BCR for a 1455 Moderate Future.

Table D - 18

Summary of Benefits for Lake Elevation 1455 (Moderate Future 2 Scenario)

	Costs for Most Likely Action Strategy				Remaining Annual Damages					Total
	Without Project	With Project	Costs Avoided	% Costs Avoided	Without Project	With Project	Damages Reduced	% Damage Reduction	Downstream Benefits	Avg Ann Benefits
West Bay Outlet - 300 cfs	$ 17,634.5	$ 12,349.3	$ 5,285.2	30.0%	$ 2,014.6	$ 1,736.0	$ 278.6	13.8%	$ (74.0)	$ 5,489.8
West Bay Outlet - 480 cfs	17,634.5	5,522.5	12,112.0	68.7%	2,014.6	962.7	1,051.9	52.2%	(4,256.0)	8,907.9
Pelican Lake Outlet - 300 cfs	17,634.5	7,246.3	10,388.2	58.9%	2,014.6	1,207.9	806.7	40.0%	(115.0)	11,079.9
Pelican Lake Outlet - 480 cfs	17,634.5	5,191.7	12,442.8	70.6%	2,014.6	962.7	1,051.9	52.2%	(2,993.0)	10,501.7
Pelican Lake Bypass - 480 cfs (PL 2)	17,634.5	7,832.9	9,801.6	55.6%	2,014.6	1,312.8	701.8	34.8%	(94.0)	10,409.4
Pelican Lake Bypass - 480 cfs (PL 3)	17,634.5	5,484.4	12,150.1	68.9%	2,014.6	756.8	1,257.8	62.4%	(95.0)	13,312.9
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	17,634.5	8,119.8	9,514.7	54.0%	2,014.6	1,417.5	597.1	29.6%	(69.0)	10,042.8

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits

Benefit-Cost Summary

	Avg Ann Costs	Total Benefits	BCR	Net Benefits
West Bay Outlet - 300 cfs	$ 5,936.0	$ 5,489.8	0.92	$ (446.2)
West Bay Outlet - 480 cfs	11,721.0	$ 8,907.9	0.76	(2,813.1)
Pelican Lake Outlet - 300 cfs	8,005.0	$ 11,079.9	1.38	3,074.9
Pelican Lake Outlet - 480 cfs	14,351.0	$ 10,501.7	0.73	(3,849.3)
Pelican Lake Bypass - 480 cfs (PL 2)	15,501.0	$ 10,409.4	0.67	(5,091.6)
Pelican Lake Bypass - 480 cfs (PL 3)	21,954.0	$ 13,312.9	0.61	(8,641.1)
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	10,246.0	$ 10,042.8	0.98	(203.2)

This Moderate Future trace for a peak lake stage of elevation 1455 is one of the 10,000 stochastic traces, and serves as a representative of approximately 25% of those traces. It rises to a peak level of 1455 at about year 2014 and then recedes for the remaining 50 years. The Moderate Future 2 results show net benefits that are slightly larger than those computed using the stochastic analysis. This could be anticipated, because the average peak lake level for the stochastic analysis was 1451.7 and the median was 1450.1. Because this trace has a higher peak lake level than the average stochastic trace, it results in larger net benefits because there are more damages to reduce. However, only one of the six alternatives had positive net benefits and a BCR greater than one—the

Pelican Lake 300 cfs constrained outlet. Note that only some of the alternatives were analyzed for this dry future. It is possible that other alternatives would show a larger net benefit.

Data in Table D-19 include the net benefits, the percent of damages prevented adjacent to the lake, the percent of costs avoided by the outlet, the peak lake level, the downstream damages avoided for each alternative, annual project costs, first costs, and BCR for a 1450 Moderate Future.

Table D-19

Summary of Benefits for Lake Elevation 1450 (Moderate Future 1 Scenario)

	Costs for Most Likely Action Strategy				Remaining Annual Damages					Total
	Without Project	With Project	Costs Avoided	% Costs Avoided	Without Project	With Project	Damages Reduced	% Damage Reduction	Downstream Benefits	Avg Ann Benefits
West Bay Outlet - 300 cfs	$ 5,681.4	$ 5,239.9	$ 441.5	7.8%	$ 916.9	$ 714.5	$ 202.4	22.1%	$ (76.0)	$ 567.9
West Bay Outlet - 480 cfs	5,681.4	3,118.5	2,562.9	45.1%	916.9	358.2	558.7	60.9%	(3,851.0)	(729.4)
Pelican Lake Outlet - 300 cfs	5,681.4	3,118.5	2,562.9	45.1%	916.9	358.2	558.7	60.9%	(132.0)	2,989.6
Pelican Lake Outlet - 480 cfs	5,681.4	3,118.5	2,562.9	45.1%	916.9	358.2	558.7	60.9%	(3,303.0)	(181.4)
Pelican Lake Bypass - 480 cfs (PL 2)	5,681.4	4,276.3	1,405.1	24.7%	916.9	702.6	214.3	23.4%	(27.0)	1,592.4
Pelican Lake Bypass - 480 cfs (PL 3)	5,681.4	3,092.8	2,588.6	45.6%	916.9	291.9	625.0	68.2%	(36.0)	3,177.6
Combination 2 (UBS, EIM, West Bay Outlet 300cfs)	5,681.4	2,343.6	3,337.8	58.7%	916.9	697.8	219.1	23.9%	(75.0)	3,481.9

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits

Benefit-Cost Summary

	Avg Ann Costs	Total Benefits	BCR	Net Benefits
West Bay Outlet - 300 cfs	$ 5,839.0	$ 567.9	0.10	$ (5,271.1)
West Bay Outlet - 480 cfs	11,357.0	$ (729.4)	(0.06)	(12,086.4)
Pelican Lake Outlet - 300 cfs	7,831.0	$ 2,989.6	0.38	(4,841.4)
Pelican Lake Outlet - 480 cfs	13,791.0	$ (181.4)	(0.01)	(13,972.4)
Pelican Lake Bypass - 480 cfs (PL 2)	15,169.0	$ 1,592.4	0.10	(13,576.6)
Pelican Lake Bypass - 480 cfs (PL 3)	21,638.0	$ 3,177.6	0.15	(18,460.4)
Combination 2 (UBS, EIM,	8,476.0	$ 3,481.9	0.41	(4,994.1)

This trace for a Moderate Future with a peak stage of elevation 1450 is one of the 10,000 stochastic traces, and serves as a representative of approximately 30% of those traces. It rises to a peak level of 1450 at about year 2014 and then recedes for the remaining 50 years. It also has a second peak near the end of the 50-year period, but the maximum lake level during the second peak is much lower than the first peak.

The Moderate Future 1 results provide net benefits that are nearly the same as those computed using the stochastic analysis. This is reasonable, because the average peak lake level for the stochastic analysis was 1451.7 and the median was 1450.1 (the same as the peak lake level for this moderate future). None of the alternatives shows a positive net benefit. Note that only some of the alternatives were analyzed for this dry future. It is possible that other alternatives would show a larger net benefit.

All of the alternatives have negative net benefits under the 1450 Moderate Future. The only positive net benefit for the 1455 Moderate Future scenario is for the Pelican Lake 300 cfs constrained outlet alternative. It is interesting to note that the ranking of the alternatives changes, depending on the scenario that is used for the analysis. Therefore, the selection of the alternative is very sensitive to the assumptions regarding the future climate condition.

Water Quality Analysis of Moderate Futures

Devils Lake consists of several bays that are somewhat isolated from each other (Pelican Lake, West Bay, Main Bay, East Bay, East Devils Lake, and Stump Lakes) and is

Dissolved solids concentrations in the lake vary both spatially and temporally. Generally, dissolved solids increase from west to east in Devils Lake as less concentrated water enters the western portion of the lake and becomes progressively more concentrated by evaporation as it moves eastward. Temporally, dissolved solids concentrations are higher in winter when ions are concentrated due to ice formation and lower in spring due to dilution by ice melt, runoff, and precipitation. Generally, each bay freshens as lake elevation rises and gets saltier during periods of stable or declining lake levels. In addition, there is now evidence that at higher lake elevations (above 1445) movement of salt from east to west is occurring due to wind seiche and density currents, diminishing the concentration gradients between bays.

Operation of an outlet would permanently remove dissolved solids from Devils Lake, as would an overflow event. The effect on water quality in the lake would be dependent on which bay the outlet removes water from, the mass of dissolved constituents removed, and the type of hydrologic regime. An outlet from East Devils Lake would remove the largest mass of dissolved solids from the lake relative to the same outlet operation from another part of the lake. Under the Wet scenario operation, flow from East Devils Lake would freshen the entire lake chain west of the Stump Lakes in a manner similar to an overflow event. The trade-off for this would be environmental changes that are unlikely to be acceptable downstream and the cost of alternative water supplies or extended water treatment. The moderate and dry future scenarios with an East Devils Lake outlet were not modeled. The in-lake effect, however, would result in much lower mass of dissolved material in the lake and fresher water within all bays except the Stump Lakes relative to a no-pump scenario.

The other outlet alternatives (West Bay and Pelican Lake) are in the western end of the lake. Generally, removal of water from the west end of the lake would limit the ability of inflows to freshen or buffer concentrations in the eastern bays. Over the first 10 years of operation under any of the hydrologic scenarios, a West Bay outlet results in sulfate concentrations slightly less than or equal to those without pumping in both West and Main Bays over the same time period. A Pelican Lake outlet would generally result in West and Main Bay concentrations somewhat greater than without pumping over the same time period. Both the Pelican Lake and West Bay outlets would cause concentration increases above the no-pump condition for East Bay, East Devils Lake and the Stump Lakes. The relative effect of these changes would be within the range of conditions that have occurred naturally in the lake.

Changes in concentrations over a longer term (10 to 50 years) are related to future hydrologic conditions. Generally, both Pelican Lake and West Bay outlets result in lower sulfate concentrations for all futures in West and Main Bay concentrations higher than the no-pump condition in the eastern bays. East Bay appears to be a pivot point in the lake and is more dependent on outlet location, volume and mass of material removed by the outlet, and recent hydrologic conditions. A West Bay outlet appears to freshen East Bay more than the Pelican Lake outlet location; however, the bay can still be more or less concentrated than the no-pump condition. Stump Lake conditions are generally dictated by the amount of inflow prevented from entering the lake. Upper Basin Storage can increase concentrations considerably under the dry hydrologic conditions.

The quality of Devils Lake (measured by sulfate or TDS) is always changing in relation to wet and dry hydrologic cycles and resulting lake levels. Use of an outlet will alter this slightly and may prevent some freshening to the eastern end of the chain. The difference from baseline, though it appears large, is still within concentration ranges the lakes have experienced in the past. In many cases, the resulting concentration ranges in the lake will be tied more closely to the hydrologic future than to outlet selection.

The water quality models, as previously described, cannot be used to directly address in-lake and downstream water quality effects in a probabilistic sense. It was only practical to run the downstream water quality model for a limited number of traces selected from the tens of thousands generated by the stochastic lake model. Stochastic traces, once selected, become scenarios. Therefore the water quality aspects of various alternatives is discussed more thoroughly later in this chapter, under the discussion of scenarios.

Moderate Future 1450 Summary of Effects during first 10 years

The concentration duration statistics cited below are from Tables 10-22 through 10-24.

300 cfs Constrained - The outlet would operate highly constrained by the sulfate limitation because the sulfate concentration in West Bay would be about 700 mg/l. With West Bay operations, the TDS standard would be exceeded 9% (2% base) of the time on the Red River near Halstad, MN and 13% (9% base) of the time at Emerson. The effect appears to be minor because only a relatively small amount of Devils Lake water would be released under the 450 mg/l sulfate constraint. Operations from Pelican Lake would *increase* the duration of those exceedances to 18% and 16% because more Devils Lake water would be released.

480 cfs Unconstrained - Operation from West Bay would cause exceedance of the ND sulfate standard for the Sheyenne River more than 20% of the time. Pelican Lake operations would reduce the exceedance at Cooperstown but increase it at Valley City because of storage in Lake Ashtabula. The TDS standards at Halstad and Emerson would be exceeded 35% (2% base)and 34% (9% base)of the time respectively. Operations from Pelican Lake would reduce the duration of those exceedances by about one third. With West Bay operation the sulfate standard at Halstad would be exceeded 11% of the time and 1% of the time at Emerson. Operations from Pelican Lake would eliminate the exceedance at Emerson but not at Halstad.

Moderate Future 1455 Summary of Effects during first 10 years

300 cfs Constrained - The outlet would operate highly constrained by the sulfate limitation because the sulfate concentration in West Bay would be close to 600 mg/l during the first few years. With West Bay operations, the TDS standard would be exceeded 14% (4% base) of the time on the Red River near Halstad, MN and 14% (11% base) of the time at Emerson. The effect is minor because only a relatively small amount of Devils Lake water would be released. Operations from Pelican Lake would *increase* those exceedances to 23% and 16% because more Devils Lake water would be released.

480 cfs Unconstrained - Operation from West Bay would cause exceedance of the ND sulfate standard for the Sheyenne River about 40% of the time. Pelican Lake operations would reduce the duration of those exceedances by about one-half. The TDS standards at Halstad and Emerson would be exceeded 63% (4 % base) and 40% (11% base) of the time, respectively. Operations from Pelican Lake would reduce the duration of those exceedances by about one-third. With West Bay operation, the sulfate standard would be exceeded 18% of the time at Halstad and 5% of the time at Emerson. Operations from Pelican Lake would reduce the exceedance at Halstad by one-half but exceedance at Emerson would be reduced only to 4%.

Dry Future Summary of Effects during first 10 years

300 cfs Constrained - The outlet would operate highly constrained by the sulfate limitation because the sulfate concentration in West Bay would be close to 700 mg/l during the first few years. With West Bay operations, the TDS standard would be exceeded 6% (4% base) of the time on the Red River near Halstad, MN and 13% (11% base) of the time at Emerson. The effects are minor because only a relatively small amount of Devils Lake water would be released. Operations from Pelican Lake would increase those exceedances to 8% at Halstad and cause no change at Emerson.

480 cfs Unconstrained - Operation from West Bay would cause exceedance of the ND sulfate standard about 21% of the time on the Sheyenne River. Pelican Lake operations would reduce the duration of those exceedances by about one-half. The TDS standards at Halstad and Emerson would be exceeded 28% (4% base) and 27% (11% base) of the time, respectively. Operations from Pelican Lake would reduce the duration of those exceedances to about 15% at Halstad and 19% at Emerson. With West Bay operation, the sulfate standard at Halstad would be exceeded 7% of the time and 1% of the time at Emerson. Operations from Pelican Lake would reduce the exceedance at Halstad to 2% and eliminate it at Emerson.

Table 10-22 - Water Quality Effects Sulfate - Percent of Time Exceeding 250 mg/l During First 10 Years (2005 - 2014)						
	Sheyenne River			Red River of the North		
Scenario	Cooperstown	**Valley City**	Kindred	Halstad	Grand Forks	Emerson
Mod50 Baseline	0	0	0	0	0	0
Mod50 300 WB	57	23	2	0	0	0
Mod50 480 WB	27	38	50	11	1	1
Mod55 Baseline	0	0	0	0	0	0
Mod55 300 WB	54	27	16	0	0	0
Mod55 480 WB	61	83	75	18	5	5
Dry Baseline	0	0	0	0	0	0
Dry 300 WB	44	11	1	0	0	0
Dry 480 WB	16	38	36	7	1	1

Table 10-23- Water Quality Effects TDS - Percent of Time Exceeding 500 mg/l During First 10 Years (2005 - 2014)						
	Sheyenne River			Red River of the North		
Scenario	Cooperstown	Valley City	Kindred	Halstad	Grand Forks	Emerson
Mod50 Baseline	83	39	68	2	0	9
Mod50 300 WB	88	89	88	9	0	13
Mod50 480 WB	87	65	89	35	12	34
Mod55 Baseline	79	34	69	4	0	11
Mod55 300 WB	84	84	84	14	0	14
Mod55 480 WB	85	94	90	63	20	40
Dry Baseline	78	49	60	4	0	11
Dry 300 WB	84	68	74	6	0	13
Dry 480 WB	82	65	72	28	11	27

Table 10-24 - Water Quality Effects Sulfate - Percent of Time Exceeding 450 mg/l During First 10 Years (2005 - 2014)						
	Sheyenne River			Red River of the North		
Scenario	Cooperstown	Valley City	Kindred	Halstad	Grand Forks	Emerson
Mod50 Baseline	0	0	0	0	0	0
Mod50 300 WB	0	0	0	0	0	0
Mod50 480 WB	22	21	23	1	0	0
Mod55 Baseline	0	0	0	0	0	0
Mod55 300 WB	0	0	0	0	0	0
Mod55 480 WB	38	44	20	0	0	0
Dry Baseline	0	0	0	0	0	0
Dry 300 WB	0	0	0	0	0	0
Dry 480 WB	10	21	14	0	0	0

Water Quality Effects of an Eroded Natural Outlet

For the wet future scenario two conditions were modeled; one in which the natural outlet route was assumed not to erode (summarized previously), and one in which the outlet route would erode in a manner that discharges a larger volume over a shorter period of time (two years). Figures 10-14 through 10-16 describe the water quality effects downstream. On the Sheyenne River at Valley City, in the no erosion scenario, the sulfate concentration would peak close to 1,200 mg/l during the second year of the event and rebound to levels above 700 mg/l during each of the subsequent six years. In the eroded scenario, a break-out discharge would occur during the third year of the event causing a sulfate concentration peak above 1,600 mg/l at Valley City. The high discharge would continue into the fourth and fifth years but the quality of the source water would improve as the lake drains eastward so that the concentration effects on the Sheyenne River would be reduced during the later years of the event relative to the no-erosion scenario.

On the Red River of the North at Halstad, in the no erosion scenario, the TDS concentration would peak above 900 mg/l during 7 out of 11 years of the overflow event. At Emerson the TDS would remain below 900 mg/l except during the winter of the 9th year in which there would be relatively low base flow. In the eroded scenario, the TDS at Halstad would peak above 3,100 mg/l during one year but remain at much lower levels during the subsequent years. At Emerson, the TDS concentration would peak above 2,200 mg/l during one year and then remain at levels not much above baseline during the subsequent years.

Figure D-17

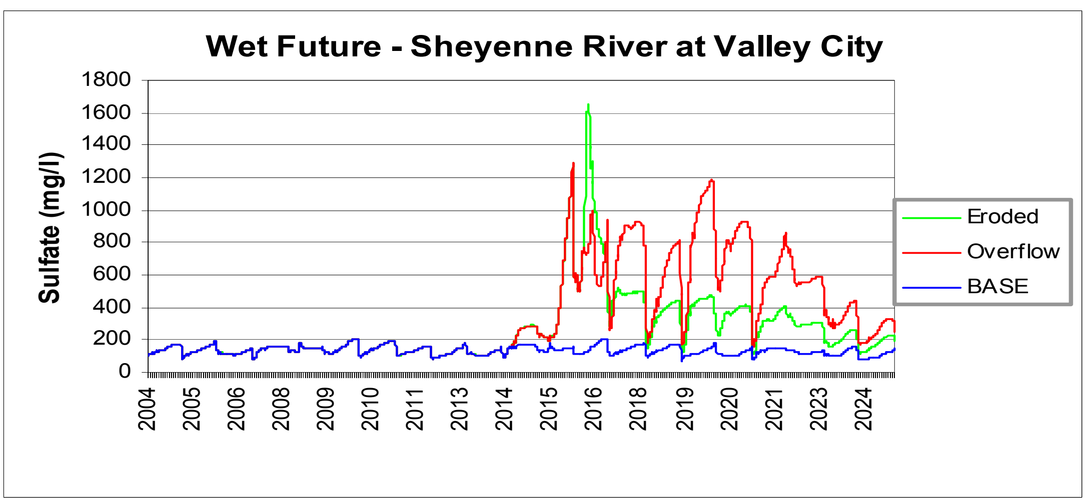


Figure D-18

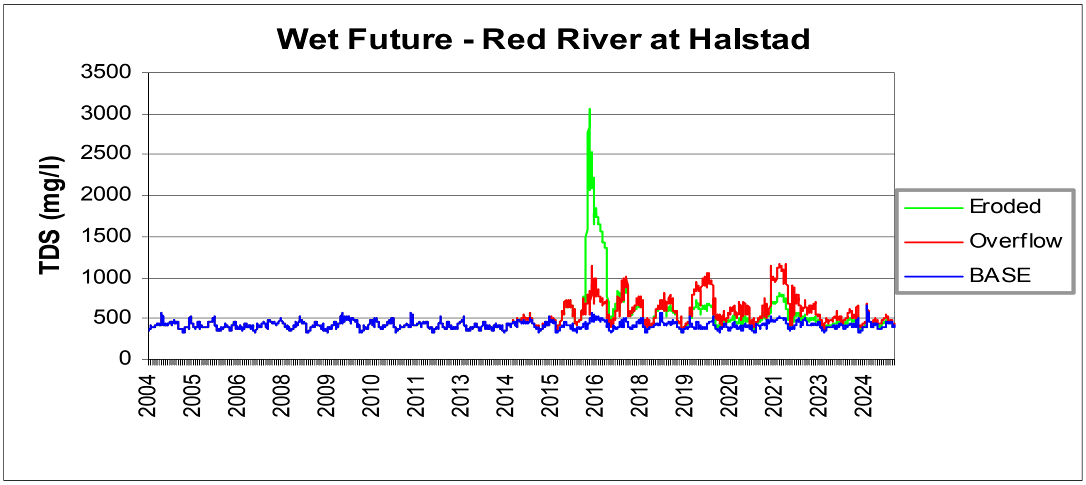
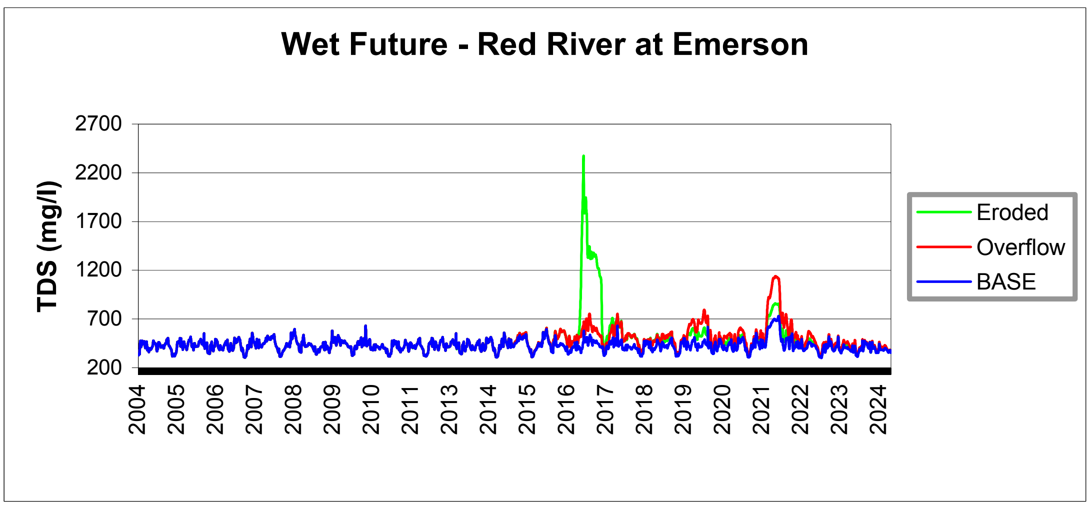


Figure D-19



OTHER ENVIRONMENTAL EFFECTS

The following alternatives were evaluated as a sensitivity to the stochastic or the wet future scenario. The sensitivity analysis assumed two moderate lake levels, erosion of the natural outlet, and a no action future in which no further actions would be taken to reduce damages due to rising lake levels. The erosion of the natural outlet was based on an analysis of the materials present at the site and the potential for them to erode and not on the possibility that the area actually eroded in the past. No action is based on a future that the actions that have occurred in the past such as road raises, levee construction, and relocations would not continue into the future. The effects of outlets are similar to the discussion presented in the stochastic/wet scenario future presented above, differing primarily in magnitude and duration. A comparative summary of the effects of the various sensitivity alternatives on the major resource areas is presented in the following Impact Matrix Table.

Table 10-26 Devils Lake Study Sensitivity Analysis

Sensitivity	Resource				
	Devils Lake Aquatic Resources	**Devils Lake Terrestrial Resources**	**Downstream Terrestrial Resources**	**Downstream Aquatic Resources**	**Biota Transfer**
No Action	Fishery in lake will continue to improve to a point. Eventually lake will recede and fishery will decline.	Wetlands, woodlands, grasslands, and other habitats will be gained and lost as lake fluctuates.	Similar to future without conditions. No effect downstream if lake does not overflow naturally. Natural overflow would have significant effect on downstream resources. Natural overflow would have significant effect on current land uses. Potential for natural overflow is small.	Similar to future without conditions. Aquatic resource could be lost depending on magnitude of overflow due to natural spill. Potential for spill is small. Not much change expected from current conditions. Fishery will maintain itself. Potential for natural overflow is small.	Unknown. Similar to future without conditions. Potential for transfer and introduction of new species may increase. Natural overflow or other water resource projects increases potential for introduction of new organisms.
Erosion of Natural Outlet	Would tend to improve water quality by removal of TDS and sulfates. Would improve natural reproduction, which may or may not be desirable for recreational fishery.	Would result in exposure of inundated areas sooner than no erosion. Would lower natural overflow elevation and change future high lake level potential.	Downstream flow resulting from uncontrolled erosions would be about 6,000 cfs causing severe erosion, loss of riparian vegetation, increased sedimentation, and degraded water quality. Significant loss of riparian zones and habitat. Recovery period would be very long.	Downstream flow resulting from uncontrolled erosions would be about 6,000 cfs causing severe erosion, loss of riparian vegetation, increased sedimentation, and degraded water quality. Significant loss of aquatic habitat, loss of species, and lower density and diversity. Recovery period would be very long.	Unknown. Similar to future without conditions. Potential for transfer of existing or introduced species increased now and for future high lake levels.
Moderate Lake 1450 - West Bay Outlet - 300 cfs	No appreciable change in aquatic resources from future without conditions. Minimal effect on lake levels and water quality.	No appreciable change in terrestrial resources from future without conditions. Little effect on lake levels.	6, 212, and 72 Natural Heritage sites located within 1/4 mile, potential groundwater influence, of Upper Sheyenne, Lower Sheyenne, and Red River, respectively. Limited effects due to operation constrained by water quality and channel capacity. Increased groundwater could affect composition of some communities. Changes in water quality could have significant effects on aquatic	Release constrained by water quality standards although increase in levels of constituents. Most effect on aquatic resources in upper Sheyenne due to increase flows. Limited effects due to operation constrained by water quality and channel capacity. Increased groundwater could affect composition of some communities. Changes in water quality could have	Unknown. Potential for transfer and introduction of new species would increase due to outlet operation. Similar to future without conditions. Potential for spread of Eurasian water milfoil due to increased flows.

			communities.	significant effects on aquatic communities. Most effect on aquatic resources in upper Sheyenne due to increased flows.	
Moderate Lake 1450 - West Bay Outlet 480 cfs	Outlet would reduce the potential for inundation of new aquatic habitat with resultant effect on fish resource. Outlet would not totally stabilize lake; therefore, some fluctuation in lake levels would continue. Fishery would decline sooner than future without conditions due to lower lake levels and increased water quality constituent levels.	Future inundation of shoreline would be reduced. Lower lake levels would expose shoreline sooner resulting in quicker successional recovery of terrestrial habitat.	Similar to West Bay 300 cfs outlet. Significant downstream effects on community structure due to degraded water quality, increased flows, and increased shoreline erosion. 25 natural heritage sites located within flooded area of Sheyenne River. Over 600 landowners potentially affected within flooded area outline. Overbank flooding could inundate almost 16,000 acres. Potential loss of riparian vegetation and shoreline vegetation due to inundation and erosion.	Degraded water quality, increased flows, increased erosion, and loss of riparian vegetation. Dramatic change in aquatic communities such as decline in invertebrate, fish, and mussel species abundance and diversity.	Similar effects as West Bay outlet.
Moderate Lake 1455 - West Bay Outlet 300 cfs	No appreciable change in aquatic resources from future without conditions. Minimal effect on lake levels and water quality.	No appreciable change in terrestrial resources from future without conditions. Little effect on lake levels.	Similar effects as West Bay 300 outlet.	Similar effects as West Bay 300 outlet.	Similar effects as West Bay outlet.

Moderate Lake 1455 - West Bay Outlet 480 cfs	Outlet would reduce the potential for inundation of new aquatic habitat with resultant effect on fish resource. Outlet would not totally stabilize lake; therefore, some fluctuation in lake levels would continue. Fishery would decline sooner than future without conditions due to lower lake levels and increased water quality constituent levels.	Future inundation of shoreline would be reduced. Lower lake levels would expose shoreline sooner resulting in quicker successional recovery of terrestrial habitat.	Similar to West Bay 300 cfs outlet. Significant downstream effects on community structure due to degraded water quality, increased flows, and increased shoreline erosion. 25 natural heritage sites located within flooded area of Sheyenne River. Over 600 landowners potentially affected within flooded area outline. Overbank flooding could inundate almost 16,000 acres. Potential loss of riparian vegetation and shoreline vegetation due to inundation and erosion.	Degraded water quality, increased flows, increased erosion, and loss of riparian vegetation. Dramatic change in aquatic communities such as decline in invertebrate, fish, and mussel species abundance and diversity.	Similar effects as West Bay outlet.